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Ballast Water Treatment, U.S. Great Lakes Bulk Carrier Engineering and Cost Study

Volume II: Analysis of On-Board Treatment Methods, Alternative Ballast Water Management Practices, and Implementation Costs

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Timothy R. Girton
Technical Director
United States Coast Guard
Research & Development Center
1 Chelsea Street
New London, CT 06320

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Reginald Wren; Mike Johnson; Nicholas Barczak; John Waterhouse, M. J. Lewandowski

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Research and Development Center
1 Chelsea Street
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SAIC
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Elliott Bay Design Group
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The R&D Center's technical point of contact is Mr. Marion J. Lewandowski, (860) 271-2692, email: M.J.Lewandowski@uscg.mil.

16. Abstract (MAXIMUM 200 WORDS)
The intent of this study is to investigate the design and ballast water management (BWM) practices of US flag vessels operating solely within the Great Lakes; assess the potential for these vessels to treat their ballast water to kill or remove living organisms; and develop a generalized evaluation of the engineering and cost issues associated with installing a BWM System.. "Ballast Water Treatment, U.S. Great Lakes Bulk Carrier Engineering and Cost Study – Volume I: Present Conditions" identifies present ballast water practices as related to trading patterns, including an analysis of ballast discharge information with respect to vessel size and type. The study selects five vessels that best represent the "full range" of U. S. flag "Laker" trade (including voyage patterns and vessel types). In "Ballast Water Treatment, U.S. Great Lakes Bulk Carrier Engineering and Cost Study – Volume II: Analysis of On-Board Treatment Methods, Alternative Ballast Water Management Practices, and Implementation Costs," we examine the costs to outfit and operate four of the five vessels with installed ballast water treatment systems, and also, for comparison, investigate potential costs associated with treating ballast water ashore.

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EXECUTIVE SUMMARY

Great Lakes bulk carriers transport large quantities of ballast water between ports during normal voyages. This transported ballast water may increase the risk of spreading invasive organisms from one region to another in the Great Lakes, negatively impacting the Great Lakes ecosystem. Ballast Water Treatment (BWT) technology may help to minimize or slow this spread of invasive species. However, bulk carriers operating exclusively within the Great Lakes (Lakers) constitute a specialized sector of the commercial fleet operating in U.S. waters, characterized by a number of design and operational aspects that are not widely encountered elsewhere and that may create significant difficulties in retrofitting vessels to meet ballast water management requirements.

Volume II of this study examines and compares various methods of commercially available BWT provided by several vendors, and evaluates potential cost and practicability of implementing selected technologies aboard Great Lakes bulk carriers. The specific work here is modeled on the potential challenge a shipowner or operator might face in determining how to implement ballast water management practices aboard a Laker. In the scenario represented here, a ship owner/operator might likely use in-house engineering staff (or contract for engineering services as done in this report) to both recommend a BWT technology, and determine how to best apply that technology aboard their vessel. In the absence of U. S. Coast Guard "type approval" of any systems to-date, the project team assumed that all evaluated systems would effectively treat ballast water to meet the USCG/IMO discharge standard.

Many of the current BWT systems are intended for ocean going trades. The particular requirements of vessels and conditions on the Great Lakes influence the effectiveness of these systems. The study considers these influences and evaluates the practicability of installing and operating current BWT systems on the Lakers. Seven different “technological processes” or treatment methods (e.g. UV, filtration, electrolytic chlorination, etc.) were found in systems, available from 21 manufacturers. In many cases, the manufacturers combined technologies for their specific “systems” (i.e., filtration and chlorination). The project considered only BWT systems that received type-approval from flag administrations in accordance with the International convention for control and management of ships’ ballast water and sediments (2004), adopted by the International Maritime Organization (IMO) , as of June 2011. The two systems selected from this evaluation for further study are: (1) filtration and ultraviolet (UV) and (2) ozonation.

The work here involves concept design to retrofit these two BWT technologies into four existing vessels, representative of U. S. flag, Great Lakes bulk carriers. Concept designs were developed for each case, including:

1. Conversion of ballast tanks.
2. Addition of new spaces and power generation and supply services.
3. Addition of a BWT system for each ballast pump on distributed ballast systems.
4. Arrangement of the components in several locations.

This approach provided a range of designs, installation requirements, and estimated costs for each design concept. Project resource constraints did not allow evaluation of a fifth vessel type (the smaller, “river-class” vessel from Volume I). With the exception of the “river-class” type Lakers, cement carriers, and a few conversions to tug-barge combinations, the four vessel types we present here represent the majority of the U. S. Flag laker fleet (see Vol. I), and design concepts could be applicable on a case-by-case, scaled basis.

The potential cost of implementing the BWT design concept was compared using two methods, actual estimated costs and *normalized* estimated cost. The normalized estimated cost was calculated by dividing the actual estimated installation cost by the deadweight of the vessel, which provides a comparison based on cargo capacity. Based on this simplified approach, the ozone approach appears less expensive than the filter/UV systems, however, in practice, the final selection of a BWT system would be based on numerous factors specific to the vessel design and operation that could result in different relative costs. Table ES-1 provides a summary of the results (rounded off) for both technology applications.

This report limits BWT system evaluation to readily available information and vendor claims. This project did not include a formal assessment of either BWT technologies or individual BWT systems, validity of vendor claims, nor BWT system actual efficacy in fresh water. The report makes no claim as to whether vendor specific equipment would be accepted by a U.S. "type approval" process. When the report uses a specific vendor name and/or product, use is solely for example purposes, particularly for applying technical specifications, including size, weight, power requirements or power output to determine installation limitations and allowances on the vessel examples. This report does not endorse any of the listed ballast water management technologies, manufacturers, or products, nor manufacturers of ancillary equipment.

Table ES-1. Summary of costs for shipboard BWT technology options.

Vessel	Deadweight (lt)	BWT 1 Filtration/UV		BWT 2 Ozone	
		Installation Cost	Normalized Cost	Installation Cost	Normalized Cost
Vessel One: Intermediate to Large Capacity 1000' Laker	62,400	$10,951,000	$175/lt	$7,731,000	$124/lt
Vessel Two: Large Capacity 1000' Laker	89,640	$11,619,000	$130/lt	$6,292,000	$70/lt
Vessel Three: Older, Small Capacity 700' – 800' Laker	25,600	$8,897,000	$348/lt	$3,457,850	$96/lt
Vessel Four: Newer, Intermediate Capacity 800' – 900' Laker	39,600	$7,944,900	$201/lt	$6,330,610	$160/lt

As an alternative to a permanent BWT system installed on each vessel, two shore-based options are considered. The concept is that vessels would connect to a shore-based BWT system at the vessel loading dock, then, pump ballast water to shore for treatment as the vessel loads cargo. The two methods for shore-based treatment are (1) using municipal sewage treatment facilities; or (2) using a dedicated BWT Facility (BWTF). Of the two, a dedicated BWTF is preferable based on the facility size and installation and operation costs. (Note: Because of limited resources, the study did not consider other alternatives: (1) a ballast-treatment "barge" with upwards of 20,000 mt tank capacity, or (2) use of treated municipal water for ballast.) Should a vessel opt for shore treatment vice shipboard installation, the vessel would be forced to load cargo only at docks (or ports) with the shore-side treatment capability. This might best apply to single-cargo vessels (e.g. cement carriers) with only a few loading facilities on the Lakes.

The study did not address whether multi-cargo vessels could practically limit voyages strictly to load-ports and docks with treatment facilities. Table ES-2 provides the estimated annual service costs of using a shore-based BWT alternative.

Table ES-2. Summary of *vessel* costs for shore-based BWT Facility.

Vessel	Ballast Capacity (mt)	Shore-based BWT Annual Cost (to vessel)		10-Yr Costs (to vessel)
		Trips	Cost/Year	
Vessel One: Intermediate to Large Capacity 1000' Laker	34,569	43	$980,000	$9.8M
Vessel Two: Large Capacity 1000' Laker	62,143	39	$1,600,000	$16M
Vessel Three: Older, Small Capacity 700' – 800' Laker	11,932	72	$580,000	$5.8M
Vessel Four: Newer, Intermediate Capacity 800' – 900' Laker	24,121	40	$640,000	$6.4M

Note: (1) Shore-based annual cost based on service rate of $0.83/cubic meters ($m^3$) of ballast water, 80% of ballast capacity discharged per trip, and dedicated BWTF used for treatment
(2) Service rate is based on total one-time dedicated BWTF construction and installation cost of $18,808,685 (amortization over 20 years at $1,639,653/year) and associated annual labor, maintenance, utility, etc. costs).

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LIST OF ACRONYMS

µm	Micrometer
µS/cm	Micro-Siemens per centimeter
A	Amps
ABS	American Bureau of Shipping
ADA	Americans with Disabilities Act
AOP	Advanced oxidation process
AOT	Advanced oxidation technology
ATB	Articulated tug and barge
BEI	Bay Engineering, Inc.
BTU	British Thermal Unit
BWM	Ballast water management
BWT	Ballast water treatment
BWTF	Ballast water treatment facility
C	Celsius
cfm	Cubic feet per minute
CO2	Carbon dioxide
EBDG	Elliott Bay Design Group
ekW	Electrical kilowatts
ft	Feet
ft^2	Square feet
gal/hr	Gallons per hour
gpm	Gallons per minute
HDPE	High-density polyethylene
HHI	Hyundai Heavy Industries
hp	Horsepower
HPU	Hydraulic power unit
hr	Hour
Hz	Hertz
IMO	International Maritime Organization
INA	Information Not Available
kg	Kilograms
KORDI	Korea Ocean Research and Development Institute
kPa	Kilopascals
kW	Kilowatt
kWh	Kilowatt hour
lb	Pounds
LCC	Life cycle cost
lt	Long ton (2240 lb)
m	Meter
m^2	Square meters
m^3	Cubic meters
m^3/hr	Cubic meters per hour
mt	Metric ton

LIST OF ACRONYMS (Continued)

NPS	Nominal pipe size
OH	Hydroxide Ion
ppm	Parts per million
psi	Pounds per square inch
PSU	Practical salinity units
PVC	Polyvinyl chloride
RDC	Research & Development Center
scfm	Standard cubic feet per minute (at 1 standard atmosphere (atm) or 14.7 psi and 60 deg F)
SWBS	Ship Work Breakdown Structure (numbering system to organize common work items and components within a ship)
TRO	Total residual oxidant
U.S.	United States
USCG	United States Coast Guard
USD	U.S. Dollar
USGS	United States Geological Survey
UV	Ultraviolet
V	Volts
WET	Whole effluent toxicity

CONVERSION TABLES

Name of Unit	Symbol	Conversion
Length		
Meter	m	
Foot	ft	= 0.3048 m
Area		
square foot	ft^2	= 0.0929 m^2
Volume		
Liter	L	
cubic foot	ft^3	= 0.0283 m^3 = 28.3168 L
Gallon	gal	= $3.7854 \cdot 10^{-3}$ m^3 = 3.7854 L = 0.1337 ft^3 = $3.7854 \cdot 10^{-3}$ mt (ρ_{fw} = 62.2 lb/ft^3)
Weight		
Kilogram	kg	
long ton	lt	= 1016 kg = 2240 lb
metric ton	mt	= 1000 kg = 2204.6 lb
net tons	nt	= 907.1847 kg = 2,000 pounds
Pounds	lb	= 0.4536 kg
Flow Rate		
gallons per minute	gpm	= $6.3090 \cdot 10^{-5}$ m^3/sec = 0.2271 mt/hr =0.2271 m^3/hr
Power		
Kilowatt	kW	
Horse power	hp	0.745 kW

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1 INTRODUCTION

1.1 Objective

The Great Lakes bulk carriers transport commodities and bulk cargo (e.g., iron ore pellets, coal, sand, gravel, etc.) throughout the lakes. In general, the commodities tend to originate in one region and vessels transport the cargo to other regions. The vessels may return to a port without cargo and need to take on ballast water to operate safely and efficiently. The transport of ballast water may move invasive species from one area to another area in the Great Lakes. This study examines several different shipboard methods to control the possible spread of invasive species using ballast water treatment (BWT), selects two potential technologies, and estimates costs for the installation on four different vessels. It also investigates alternative, non-ship installed options.

1.2 BWT Systems

BWT equipment to reduce the probability of biological invasions by non-indigenous species via ship operations is being marketed. Most of the existing BWT systems are installed and tested on ocean-going ships. In the absence of systems type-approved by the Coast Guard[1], this study conducted a survey of those systems with International Maritime Organization- (IMO) approval for using active substances where pertinent, and Flag Administration type approval in accordance with the international ballast water management convention, for their application on the Great Lakes. Potential systems considered in this study include:

1. Filtration + Ultraviolet (UV) radiation.
2. Chlorine dioxide with or without filtration
3. Sodium hypochlorite with or without filtration.
4. Ozone treatment.

This study selects two BWT systems to install on four of the five vessels identified in Volume I of this report.

1.3 Vessel Examples

The vessels that operate on the Great Lakes vary in age, type of construction, and cargo carried. The installation of a BWT system will vary from class of vessel and individual vessels. The study considered the following design constraints:

1. Existing machinery space to add BWT system.
2. Creating a new machinery space, if necessary.
3. Availability to use existing equipment.
4. Amount of additional support (e.g., electrical generator) needed.

[1] While this study was being completed, the Coast Guard published a final rule on 23 March, 2012, that included the IMO ballast water discharge standard and the requirement for Coast Guard type approval of shipboard BWMS used to meet the discharge standard.

Five vessels were selected that best represented the full range of trade routes, ballast water transport, and vessel type among Lakers (see Vol. I). Of the five vessels, four vessels were chosen to evaluate the installation of two different types of BWT systems on each vessel. The vessels are:

1. 1000' bulk carrier with a single header-per-side ballast system.
2. 1000' bulk carrier with a ballast system for each ballast tank.
3. 768' bulk carrier with an individual ballast line to each tank.
4. 740' bulk carrier barge with a single header-per-side ballast system.

This study provides an overview of the BWT technologies and available administration-approved systems. The study evaluates the approved systems based on:

1. Suitability for operating in the Great Lakes.
2. Size of the equipment.
3. Operational requirements.
4. Cost of the equipment.

The installation of the two systems provides insight in the practicality for purchasing, installing, and operating a BWT system. The study demonstrates:

1. Challenges and possible design solutions for the installation of the BWT systems.
2. Space requirements for the selected vessels and systems.
3. Cost for the equipment and installation.
4. Operational cost after the installation.

1.4 Alternate Methods

The installation of BWT systems could have a great impact on the vessel operations. Because of this, we also evaluated alternate approaches to ballast water management (BWM) using existing municipal sewage treatment systems, and building dedicated shore-based BWT facilities. The study considers:

1. Vessel modifications required to install a ballast water transfer system.
2. Handling requirements to connect the ship's discharge system to the shore-based transfer system.
3. Infrastructure and operational modification to existing municipal systems to handle large amounts of ballast discharged.
4. Dockside infrastructure to pump the ballast water to either an existing municipal sewage system or a dedicated BWT system.

The resulting work identifies the physical space requirements for a shore-based BW treatment system, cost for vessel modifications, concepts for shore-side handling of the connection between the vessel and shore-based system, and the significant shore-side infrastructure needed for either method. The report does not address administrative delays and costs for site-plan approval, easements and other permitting requirements.

2 BWT SYSTEMS AND TECHNOLOGIES

Efforts by industry to meet the challenge of effectively preventing the transport of invasive species in ships' ballast water are bringing a wide array of BWT systems to the market. BWT systems employ a variety of chemical, physical, or mechanical processes to remove or inactivate organisms living in ballast water.

Depending on the BWT design, the system may operate during uptake of ballast, while underway, upon discharge, or a combination of these. As of December 2011, there were over 45 different systems in various stages of development and regulatory approval. The IMO, under the International Convention for the Control and Management of Ships Ballast Water & Sediments (IMO, 2004) (the "convention"), has led the international effort to regulate and develop BWT efficacy standards and testing protocols. Twenty-one of the 45 systems have received Flag-Administration Type Approval Certification.

2.1 General BWT System Information

This study considers 21 BWT systems that received type approval by an administration in accordance with the convention, prior to October 2010. Table 1, compiled from IMO (October 2010) and Albert, et al. (2010), provides an overview of the 21 systems, including brand name, manufacturer, and technology. Each system has a number to assist in identifying the technology/technologies) used. One system (Alfa Laval PureBallast® System (ID #17) was said by the manufacturer to be not available at the time for the Great Lakes market. Two other systems (Hitachi ClearBallast (ID #8) and SEDNA® Ballast Water Management System (ID #19)) were available, but temporarily withdrawn by the manufacturer from the Great Lakes market for technical reasons at the time of this study. These 20 available systems (including ID #8 and ID #19) share seven common technologies used to remove, kill or inactivate organisms carried in ballast water.

Table 1. Manufacturers and BWT systems.

ID #	Name of System	Manufacturer	System Description
1	"ARA Ballast" Ballast Water Management System	21st Century Shipbuilding Co., Ltd.	50 micrometer (µm) automatic back-flushing screen filter, plasma arc shockwave destr uction, disinfection with UV light
2	BalClor™ Ballast Water Management System	Sunrui Corrosion and Fouling Control Company	50 µm automatic back-flushing screen filter, electrochlorination (electrolytic generation of sodium hypochlorite in side stream), neutralization on discharge
3	CleanBallast Ballast Water Management System	RWO Marine Water Technology	55 µm automatic back-flushing disc filter, electrolysis-electrochlorination, advanced oxidation (generation of OH radicals)
4	Ecochlor® Ballast Water Management System	Ecochlor, Inc.	50 µm automatic back-flushing filter, disinfection with injected chlorine dioxide (chlorine dioxide is generated onboard from two component chemicals, sulfuric acid and Purate®)
5	Electro-Cleen™ System	Techcross Ltd. and Korea Ocean Research and Development Institute (KORDI)	Electrolysis-electro chlorination, generation of OH radicals, neutralization on discharge
6	GloEn-Patrol™ Ballast Water Management System	Panasia Co., Ltd.	50 µm automatic back-flushing screen filter, disinfection with UV light
7	Sedinox® Ballast Water Management System	Hamworthy Greenship, Ltd.	Hydrocyclonic separation, disinfection sodium hypochlorite generator

Table 1. Manufacturers and BWT systems. (Continued)

ID #	Name of System	Manufacturer	System Description
8	ClearBallast Ballast Water Management System	Hitachi, Ltd./Hitachi Plant Technologies, Ltd.	Pre-coagulation, flocculation, magnetic separation, filtration
9	Hyde GUARDIAN® Ballast Water Management System	Hyde Marine, Inc.	55µm automatic back-flushing disc filter, disinfection with UV light
10	HHI Ballast Water Management System (EcoBallast)	Hyundai Heavy Industries (HHI) Co., Ltd.,	Filtration, disinfection with UV light
11	JFE BallastAce Ballast Water Management System	JFE Engineering Corporation	50 µm automatic back-flushing filter, sodium hypochlorite (stored in onboard tank and injected into ballast stream), cavitation, neutralization on discharge
12	NEI VOS™ Treatment System	NEI	Deoxygenation and cavitation
13	NK-O3 BlueBallast System	NK Company, Ltd.	Ozone, neutralization on discharge
14	OceanGuard™ Ballast Water Management System	Qingdao Headway Technology Co., Ltd.	50 µm filtration, electrolysis-electrochlorination advanced oxidation process (AOP), generation of OH radicals, ultrasound, neutralization on discharge optional
15	OceanSaver® Ballast Water Management System	MetaFil, AS.	40 µm automatic back-flushing filter, electrochlorination (electrolytic generation of sodium hypochlorite in side stream), cavitation, deoxygenation option, neutralization on discharge
16	OptiMarin Ballast System	OptiMarin	40 µm automatic back-flushing filter, disinfection with UV light
17	PureBallast® System	Alfa Laval	40 µm automatic back-flushing filter, photo catalytic advanced oxidation technology (AOT), generation of OH radicals
18	Unitor Ballast Water Management System	Wilhemsen Technical Solutions/Resource Ballast Technologies (Pty), Ltd.	40 µm automatic back-flushing filter, cavitation, electro-chlorination (sodium hypochlorite generated in ballast stream), ozone
19	SEDNA® Ballast Water Management System	Degussa, GmbH	50 µm automatic back-flushing filter, hydrocyclone, injected biocide Peraclean® Ocean (peracetic acid)
20	BalPure® Ballast Water Management System	Severn Trent De Nora, LLC	Electrochlorination (electrolytic generation of sodium hypochlorite in side stream), neutralization on discharge
21	SP-Hybrid BWMS Ozone version	Mitsui Engineering & Shipbuilding Co., Ltd.	Hydrodynamic shear, cavitation, ozone

The seven common technologies used to remove, kill, or inactivate organisms carried in ballast water are:

1. Filtration is the process of removing particulate matter from a fluid stream. The filter system is equipped with a back-flushing system for cleaning the filters. Filtration systems are used to reduce sediment loading and remove larger organisms. The removal of the sediment increases the effectiveness of other technologies. Systems using this technology are ID #s 1, 2, 3, 4, 6, 9, 10, 11, 13, 14, 15, 16, 17, and 18.
2. UV radiation causes a photochemical reaction in biological cells that kills or renders infertile entrained organisms. UV is successful in the treatment of drinking water. Systems using this technology are ID #s 1, 6, 9, 10, and 16.
3. One system uses chlorine dioxide technology, ID #4. Chlorine dioxide is produced through the reaction of two make-up chemicals, and dosed into the ballast water.
4. The systems using chlorination with sodium hypochlorite technology are ID #s 2, 3, 5, 7, 11, 14, 15, 18, and 20. Sodium hypochlorite is generated onboard through electrolysis, and/or carried in tanks loaded from shore.
5. Advanced oxidation generates hydroxide ion (OH) radicals. The OH radicals injected into the ballast water control the spread of the invasive species. The cells are killed by lost enzyme activity and decomposed by the hydroxyl ion radical. Systems using this technology are ID #s 3, 14, and 17
6. Ozone is an oxidizing agent alternative to chlorine or chlorine dioxide used for sterilization. Systems using this technology are ID #s 13, 18, and 21.
7. Deoxygenation is removal of oxygen from the ballast water. This is done by supersaturating the ballast water with an inert gas. The resulting lack of dissolved oxygen suffocates the microorganisms. Systems using this technology are ID #s 12 and 15.

In many cases, systems combine less common BWT technologies such as cavitation, plasma arc shockwave, ultrasonic treatment, or hydrodynamic shear. A detailed discussion of the various BWT technologies, extensively documented in other literature, is outside the scope of this report. Refer to Lloyds Register (February 2010), American Bureau of Shipping (April 2011), and Albert (June 2010) for additional information on the various BWT technologies.

2.2 Application of BWT Systems to the Great Lakes Fleet

The Laker fleet operating conditions present circumstances, that when taken together, impose challenges to ballast water treatment systems. For the most part, trips among Great Lakes ports are short (ranging from hours to only a few days), the vessels are designed to minimize loading and unloading times, with high-capacity flow ballast systems relative to vessel size (2,000 cubic meters per hour (m^3/hr) to 10,000 m^3/hr), and the Great Lakes are fresh water, with temperatures below 15 ºC for the majority of the year. Therefore, a treatment system for exclusive use under these conditions on the Great Lakes must be based on minimum treatment-hold time, allow very high capacity flow-through, and be capable of treating fresh, cold water.

2.3 Operational Impact and Costs

Table 2 summarizes cost and basic technical attributes of the BWT systems surveyed. Data was compiled from Lloyds Register (February 2010), data published on vendors' websites, and direct correspondence with vendors. Where operational cost information was not available, it was estimated based on the cost of generated electrical power, assuming $3.50/gallon marine distillate/diesel fuel cost (MARAD (2013) & Smith (2013)). As shown in Table 2, the BWT systems vary considerably in terms of total power consumption, required footprint, initial purchase costs, and estimated operational costs.

Note: Only eight vendors provided responses to queries, so only partial system information is available in this report. Where information is not available in Table 2, the acronym INA (Information Not Available) is inserted.

The short-duration trips with large volumes and high ballasting/deballasting rates that characterize Laker operations require equally large BWT systems. Lakers are most commonly arranged with separate ballast systems on opposite sides of the vessel, often with a cross-over connection between the two for redundancy. On the largest vessels, each side may have a maximum pumping rate of about 5,900 m^3/hr. The maximum flow rate for most BWT systems ranges between 5,000 and 8,000 m^3/hr (Table 2) necessitating the installation of two BWT systems.

The typical engine room in a Laker is crowded, with little space to accommodate new machinery. On most vessels, conversion of existing ballast tanks adjacent to the engine room, addition of a mezzanine machinery space inside an existing engine room, creation of new machinery spaces adjacent to the vessel's current superstructures, or other modifications above deck will be required to accommodate a BWT system. Electrical load requirements are also significant, and many vessels will not have sufficient generating capacity to accommodate the additional electrical load to support a BWT system. In this case, additional generators must be purchased and installed. As a result, the capital cost for supporting equipment and structural modifications can be expected to meet or exceed the cost of the BWT system itself. American Bureau of Shipping (April 2011) and Lloyds Register (February 2010) provide further discussion of these cost issues.

The potential for increased rates of corrosion in ballast tanks is a significant potential side effect of some BWT systems. Lakers may be particularly sensitive to increased corrosion, as anti-corrosive coatings are not commonly applied due to the relatively low rates of natural steel corrosion in freshwater (Weakley (2012)). The ABS Ballast Water Treatment Advisory (American Bureau of Shipping, April 2011) notes that there is little conclusive data or long-term field experience validating the corrosion effects on ballast tanks of the various BWT technologies. Replacement and vigilant maintenance of ballast tank coatings may be required in some instances.

Table 2. BWT system requirements.

ID #	Name of System	Capital Cost ($/m³/hr)[1]	Operation and Maintenance Cost ($/1000m³)	Capacity Range (m³/hr)	Consumables	Potential Discharge Contaminants[2]	Average Power Draw (kilowatt hour (kWh)/m³) (in fresh water)[3]	Footprint (square meters (m²))[3]	Impact on Ballast Tank[4]	Website
1	"ARA Ballast" Ballast Water Management System	INA	INA	INA	--	None	INA	INA	Decreased sediment	--
2	BalClor Ballast Water Management System	INA	49.6 (including cost of salt)	100-5000 (>10000)	Salt for sodium hypochlorite generation in fresh water, sodium thiosulphate neutralizer	Yes	0.05	5-14	Decreased sediment, potential corrosion increase (see Section 2.3)	http://www.sunrui.net/Products/BalClorTMBallastWaterManagementSystem/
3	CleanBallast Ballast Water Management System	INA	INA	150-3750	--	Yes	INA	INA	Decreased sediment	www.rwo.com
4	Ecochlor Ballast Water Management System	400	80	250-8000 (10000)	Sulfuric Acid and Purate for ClO_2 generation	Yes	0.005-0.028	8-18	Decreased sediment, potential corrosion increase (see Section 2.3)	http://www.ecochlor.com/index.php
5	Electro-Cleen System	300	13.5 (est. cost of power)	300-1000	Neutralizer	Yes	0.07	3-7	Potential corrosion increase (see Section 2.3)	www.techcross.com
6	GloEn-Patrol Ballast Water Management System	400	22 (est. cost of power)	150-6000	--	None	0.12	3-59	Decreased sediment	http://www.gloen-patrol.com/
7	Sedinox Ballast Water Management System	INA	INA	100-1000	--	Yes	INA	1-10	Decreased sediment, potential corrosion increase (see Section 2.3)	www.hamworthy.com
8	ClearBallast Ballast Water Management System	INA	INA	200-2400	Magnetic powder, coagulant	Yes	.06-.07	25-209	Decreased sediment	http://www.hitachi-pt.com/products/es/ballast/index.html
9	Hyde GUARDIAN Ballast Water Management system	354	20.2 (est. cost of power)	60-6000	--	None	.065 - .110	3-51	Decreased sediment	http://www.hydemarine.com/ballast_water/index.htm
10	HHI Ballast Water Management System (EcoBallast)	INA	23.1 (est. cost of power)	Up to 4000	--	None	0.125	10-29	Decreased sediment, potential corrosion increase (see Section 2.3)	http://english.hhi.co.kr/
11	JFE BallastAce Ballast Water Management System	INA	53	Up to 4500	Sodium hypochlorite, sodium sulphite	Yes	0.003	INA	Decreased sediment, potential corrosion increase (see Section 2.3)	http://www.jfe-eng.co.jp/
12	NEI VOS Treatment System	335	130	300-6800 (>10000)	-	None	.02-.03	3-18	Decreased corrosion	http://www.nei-marine.com/
13	NK-O3 BlueBallast System	500	13.5 (est. cost of power)	250-8000 (>10000)	Sodium thiosulphate neutralizer	Yes	.08	4-37	Potential corrosion increase (see Section 2.3)	http://www.nkcf.com/
14	OceanGuard Ballast Water Management System	INA	9.4 (est. cost of power)	50-9350 (10000)	Neutralizer (when equipped)	Yes	0.05	INA	Decreased sediment, potential corrosion increase (see Section 2.3)	http://www.headwaytech.com/en/fist.ASP
15	OceanSaver Ballast Water Management System	333	57.6 (est. cost of power, includes cost of salt)	Up to 5000	Salt for sodium hypochlorite generation in fresh water, citric acid monohydrate, sodium thiosulfate neutralizer	Yes	.05	to 32	Decreased sediment, potential corrosion increase (see Section 2.3)	http://www.oceansaver.com/

Table 2. BWT system requirements. (Continued)

ID #	Name of System	Capital Cost ($/m³/hr)[1]	Operation and Maintenance Cost ($/1000m³)	Capacity Range (m³/hr)	Consumables	Potential Discharge Contaminants[2]	Average Power Draw (kilowatt hour (kWh)/m³) (in fresh water)[3]	Footprint (square meters (m²))[3]	Impact on Ballast Tank	Website
16	OptiMarin Ballast System	640	19.4 (est. cost of power)	167-3000 (>10000)	--	None	0.11	3-13	Decreased sediment	http://optimarin.com/
17	PureBallast System	INA	18.5 (est. cost of power)	250-3000 (>10000)	--	None	0.125	3-13	Decreased sediment	http://www.alfalaval.com/solution-finder/products/pureballast/Pages/Pureballast.aspx
18	Unitor Ballast Water Management System	350	2.8 (est. cost of power)	150-4000 (>10000)	--	Yes	0.01-0.02	2-8	Decreased sediment, potential corrosion increase (see Section 2.3)	http://www.wilhelmsen.com
19	SEDNA Ballast Water Management System (Safe Effective Deactivation of Non-Indigenous Aliens)	INA	200	2000	Peraclean® Ocean (peracetic acid)	Yes	INA	INA	Decreased sediment	http://www.sjofartsdir.no/upload/29160/SEDNA%20Voigt.pdf www.hamannag.eu
20	BalPure Ballast Water Management System	350	59.6 (includes cost of salt)	500-5000 (>10000)	Salt for sodium hypochlorite generation in fresh water, neutralizer.	Yes	0.03-0.05	7-18	Decreased sediment, potential corrosion increase (see Section 2.3)	http://www.severntrentservices.com/en_us/index.aspx
21	SP-Hybrid BWMS Ozone version	INA	INA	INA	INA	INA	INA	INA	INA	http://www.mes.co.jp/english/

[1]The estimated capital cost is based on the amount of ballast water a system can treat. The best measure is the flow rate of a system. The cost of a system divided by the flow rate provides a method to compare systems costs (Lloyds Register, February 2010).
[2]Detailed information on the compounds discharged by the various systems is outside the scope of this report. Systems noted 'Yes' use biocides or other active substances, such as sodium hypochlorite or ozone, and have the potential to discharge residual toxic compounds with treated ballast water. Discharge levels are subject to IMO standards as well as pending Federal and current State regulations. Whole effluent toxicity (WET) testing is required to obtain IMO approval, and results of these tests may be obtained through the vendor or IMO.
[3]These values are nominal values representing a range of design and operating conditions.
[4]The potential reduction of waterborne sediment is limited to those sediments or particles greater than filter-mesh or filter pore size.

The cost of power to run the BWT systems and the cost of chemical additives drives the operational and maintenance costs. Due to frequent ballasting and deballasting, ongoing operational costs will be significant. Estimated BWT system operational costs obtained by Lloyds Register (February 2010) range from around \$10/1000 m^3 to \$80/1000 m^3 of treated ballast water. From Table 6 in Volume I of this report (*Vessel information for the top 25 vessels by volume of ballast water discharged for 2010*), the top 10 Lakers (ranked according to total quantity of ballast water discharged in 2010) discharged between ~1.62 million and ~2.28 million mt each in 2010. Assuming 1.7 million mt of ballast water discharged in a single year, system operating and maintenance costs priced at \$10/1000 m^3 result in an annual cost of \$17,000. At \$80/1000 m^3, this same 1.7 million mt of ballast water costs ~\$136,000 per year to operate and maintain the BWT equipment.

There are several other potential operational impacts which are not directly reflected in the operational costs noted above. Ballast uptake rates are reduced by increased pressure losses in the ballast system or diversion of ballast water for filter back-flushing. Minimum treatment-hold time may affect how soon after uptake discharge can occur; this includes time requirements for active substance neutralization. Conversely, ballast water filtration at the point of intake may provide an ancillary benefit in the potential reduction of both the frequency and level of effort required to clean ballast tanks of waterborne sediment, specifically those sediments greater than filter-mesh (or pore) size.

3 SYSTEM SELECTION

3.1 Selection Criteria

In order to select BWT systems for this study, each general technology is evaluated against three primary criteria intended to gauge each technology's basic applicability to the Great Lakes.

1. The system must function effectively in fresh water, with salinity <1 practical salinity units (PSU).
2. The system must function effectively in the full range of water temperatures experienced throughout the Great Lakes (Figure 1 below).
3. The system must be effective without requiring ballast be held onboard for extended periods.

BWT technologies meeting these criteria are compared across 10 additional criteria in order to evaluate their relative economic and operational impact. The scoring matrix in Section 3.2 tabulates scores for each criterion to determine which system(s) are most applicable to Great Lakes vessels.

It is also important to note that, while these criteria provide a good indication of whether or not a particular BWT technology is applicable to the Great Lakes, they are not inclusive of all potential differences between the Great Lakes and saltwater ocean conditions. This study did not include potential differences in sediment loading (including size of sediment particles) nor potential differences in size and species of organisms. Successful testing in accordance with IMO guidelines does not necessarily guarantee compliance with U.S. Federal regulations.

3.1.1 Fresh Water

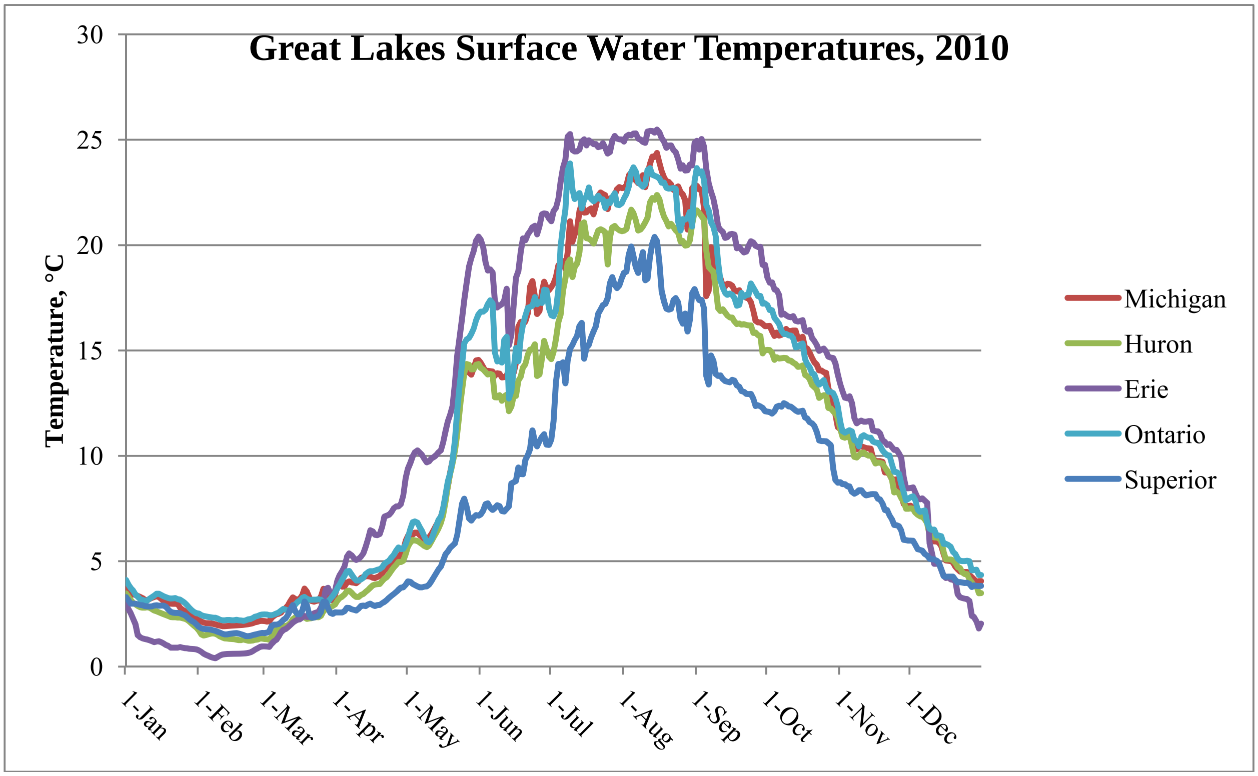
The waters of the Great Lakes have low salinity levels typical of many inland fresh water lakes. Duluth/Superior harbor, for example, typically ranges between 0 to 1 PSU, with conductivity on the order of 250 micro-Siemens per centimeter (µS/cm) as reported in testing by the Great Ships Initiative (Cangelosi, April 28, 2010). United States Geological Survey (USGS) data shows similarly low values elsewhere in the Great Lakes (Cangelosi, March 15, 2010; USGS, Accessed July 20, 2011). Seawater, by contrast, typically has salinity around 35 PSU (~56,000 µS/cm). IMO BWT testing guidance recommends testing at two salinity levels separated by 10 PSU, but does not require testing at the low salinity levels seen in the Great Lakes (Marine Environmental Protection Committee, IMO, October 2008). Only those systems for which testing data is available or the vendor has confirmed effectiveness in fresh water are included for this study. The study did not independently validate manufacturers' claims.

BWT technologies which apply electric current to ballast water (electrolysis) are affected by low salinity water. In particular, those systems that rely on generation of sodium hypochlorite in the main ballast stream will not be effective. Specific modifications to systems that generate sodium hypochlorite in a side stream allow for operation in fresh water. This requires the addition of a brine system (or other source of ions, such as stored seawater) to increase the salinity of the water feeding the hypochlorite generation equipment. Three of the four advanced oxidation based systems reviewed rely on electrolytic generation of OH radicals for treatment of ballast water. They are reported in marketing literature as effective in fresh water; however, electrical requirements increase with decreasing salinity. Of three vendors of advanced oxidation systems that replied to inquiries, one indicated that their system is not effective in water with conductivity less than 1000 µS/cm (Schloericke, June 7, 2011) and the other two stated that their system was effective in fresh water with an increase in electrical requirements (Techcross, February 2011; Michalak, June 20, 2011).

3.1.2 Cold Water

As shown in Figure 1, surface water temperatures in the Great Lakes vary seasonally from 0 ºC to 25 ºC. Temperatures are generally above 15 ºC mid-June through October and below 5 ºC from mid-December through late April. Average temperature also varies from lake to lake, with Lake Superior showing consistently lower temperatures throughout the year. Ballast water uptake occurs at depths of 3 to 8.5 m (10' to 28') below the surface. Due to naturally occurring temperature gradients, incoming ballast water can be 5 ºC to 15 ºC colder than surface water in the summer months (Assel, March 1985; NOAA, Accessed July 20, 2011).

Electrolytic generation of sodium hypochlorite degrades in efficiency below 15 ºC, and is ineffective below 5 ºC. Some BWT systems pass only a small portion of the ballast water as a side stream through an electrolysis unit to generate sodium hypochlorite. These systems could be fitted with a heater when operating in low temperature waters. Systems that generate hypochlorite in the main ballast stream cannot be cost effectively modified, as heating the entire ballast water stream by 10 ºC to 15 ºC is not practical (Severn Trent De Nora, March 2011).



Source: Temperature data from NOAA Coastwatch (Accessed: June 11, 2011)

Figure 1. Great Lakes surface water surface temperatures.

3.1.3 24-Hour Hold Time

Many treatment systems require retaining ballast water for a certain amount of time prior to discharge (hold time). This either guarantees sufficient contact time for effective treatment, or allows residual biocides to degrade prior to discharge. Systems relying on deoxygenation require ballast hold times in excess of 48 hours to be effective (American Bureau of Shipping, April 2011). Current Michigan regulation requires a hold time of 24 hours for chlorine dioxide-based treatments and 19 hours for sodium hypochlorite-based treatments (State of Michigan Department of Environmental Quality, October 11, 2006). For systems using biocidal treatments (chlorine dioxide, sodium hypochlorite, etc.), discharged ballast water must also be sufficiently free of residual biocides so that aquatic life in the receiving water is not affected. Some of these systems rely on minimum hold time to allow for degradation of residual biocides; others use chemical neutralization (American Bureau of Shipping, April 2011).

Figure 2 shows distributions of operational ballast water hold times for different vessel types as discussed in Section 3 of Volume I of this report. Most discharges of vessel ballast water transported throughout the Great Lakes occur between 24 hours and 96 hours after uptake. In 2010, only 6 percent of the ballast water discharged by the Laker fleet occurred less than 24 hours after uptake. This statistic generally indicates that BWT systems that allow safe discharge of treated ballast in 24 hours or less will have low impact on current operations.

The results also show that there are considerable operational differences between vessels. For example, a BWT system which requires ballast retention longer than 24 hours might be acceptable for installation on the “Large Capacity 1000’ Laker” but would not be acceptable for vessels which routinely make shorter runs, such as the “Small Capacity, River Class 600’ - 700’ Laker.” Ultimately, the requirement will depend

on a vessel's specific operational profile. For the purposes of this study, only those BWT systems that did not identify a required hold-time were considered. With this, the study made the assumption that if a required hold time wasn't specified, there wasn't one, and such systems allowed discharge of ballast water within 24 hours of treatment. The crux of the study was to determine issues and expected costs associated with installation and operation of a BWT system, not to identify a "best" system for any given vessel.

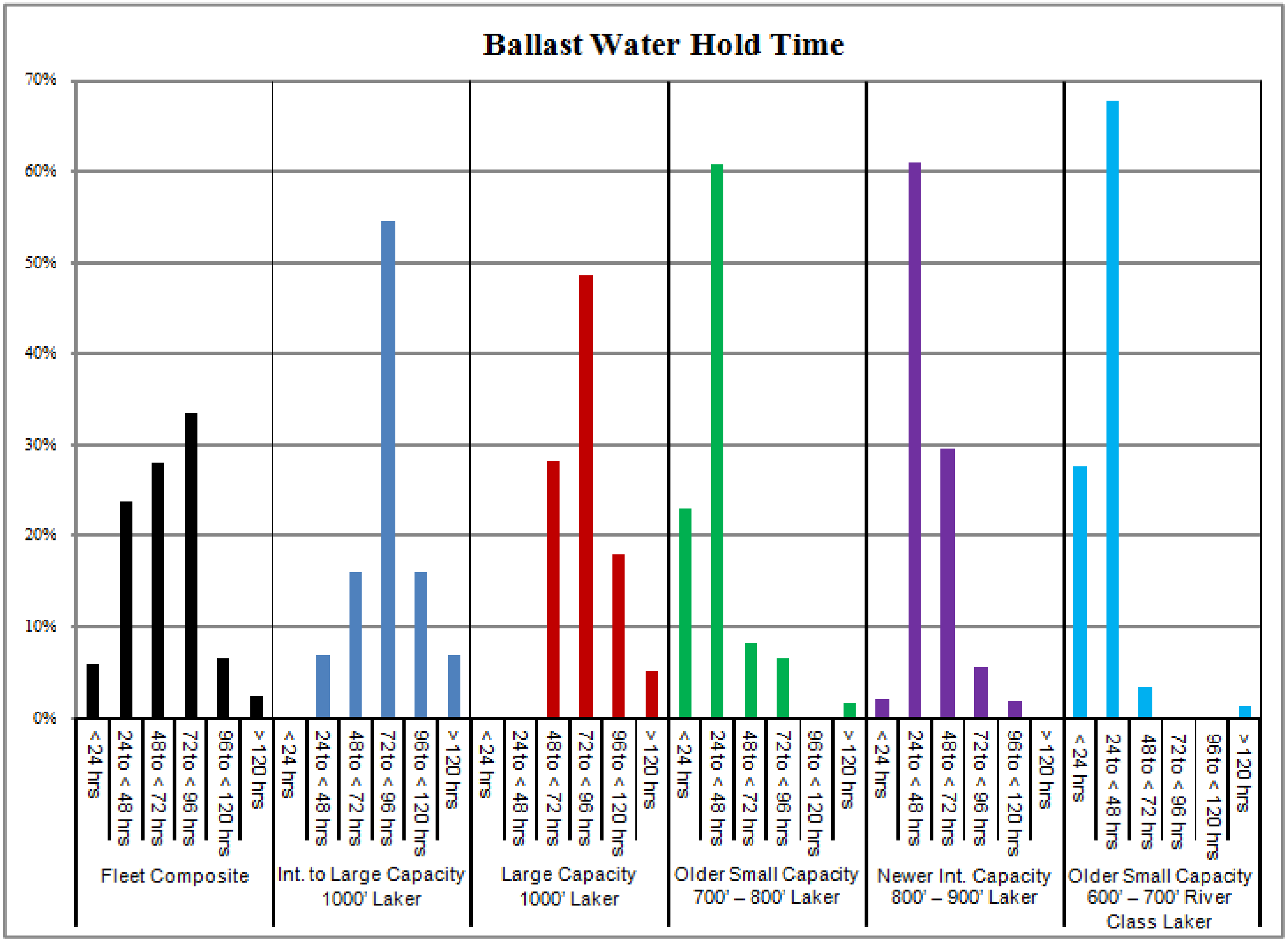


Figure 2. Ballast water hold time.

3.1.4 Economic Impact

BWT systems meeting the three primary criteria are graded on six quantitative and four qualitative measures to evaluate their relative economic impact on vessel operations. Unless otherwise noted, each score represents a percent deviation from the average score for that criterion. Higher scores indicate lower cost or positive impact on operational cost; lower scores indicate the opposite. The scoring criteria are as follows.

3.1.4.1 Quantitative Criteria

- System Footprint: The space required for the system, based on published dimensions of the system, with adjustments for anticipated complexity of installation, such as additional piping or other components that would be required but not represented in the basic system dimensions

- Consumable Volume: The BWT system's required volume of consumables, estimated assuming 2 weeks endurance between resupply. The maximum score of 100 percent represents no consumables. Consumables score less than 100 percent represent some consumables required. The smaller the number, the more space required for consumables.
- Electrical Power Consumption: Additional power required beyond ship's normal electrical loads to operate the BWT system
- Pressure Drop: Estimated additional pressure drop the BWT system will impose on the vessel's ballast system, based on vendor-reported data
- Initial Capital Cost: Estimated capital cost of technology
- Operation and Maintenance Cost: Estimated operation and maintenance cost, inclusive of power and consumable costs

3.1.4.2 Qualitative Measures

- Operation Complexity: Estimated operational complexity of the system, including added maintenance, handling of chemicals, and other consumables
- Effect on Ballast Transfer Rate: Estimated effect technology will have on ballasting rate; this category is qualitative, and primarily driven by filtration back-flushing
- Effect on Corrosion: Estimated effect on ballast tank and piping corrosion relative to existing ballast water systems' scores for this category represent only qualitative measures based on limited data
- Effect on Sedimentation: Estimated effect technology has on ballast tank sedimentation; filtration systems remove larger particles (>40-50 μ) and may reduce the total sediment load, however much sediment in ballast water is smaller than the filter-mesh size and might not be removed.

3.2 System Comparison Matrix

Table 3 is a system scoring matrix that shows the compiled scores for each BWT system. The goal of the comparison is to select two different technologies, not individual systems or vendors. Systems, not vendors, are grouped by common technology. A weighting factor assigned to each criterion represents its relative importance to the overall life-cycle cost of the system.

In its current state, the system comparison matrix is of limited utility and does not allow a full comparison of BWT systems. ***Most of the 19 vendors did not fully respond to repeated requests for information or cost data;*** thus, a large portion of the vendor data is either missing or requires further verification. The version of the Lloyds Register Current Status Report (Lloyds Register, February 2010) available at the time of the analysis provided data used to estimate preliminary BWT system capital and operation and maintenance costs. Where electrical requirements were available, the cost of power is calculated and used as an estimate of operation and maintenance cost.

There are, however, broad trends identified from the matrix. The weighted scores of similar technologies fell into broad clusters, giving an indication of which technologies provide potentially-lower, overall life-cycle costs.

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Table 3. Ballast treatment technology scoring matrix.

	Compatible With		Hold Time	Quantitative Measures						Qualitative Measures					
Technology Description	**Fresh Water**	**0-25°C Water**	**24 Hours or less**	**System Footprint**	**Consumable Volume**	**Electrical Reqt**	**System Pressure Drop**	**Initial Capital**	**Operation and Maintenance**	**Operational Complexity (Note 1)**	**Ballast Rate Effect (Note 2)**	**Corrosion Effect**	**Sedimentation Effect**	**Weighted Score**	**Notes**
Weighting Factor:	Yes Req'd	Yes Req'd	Yes Req'd	20.0%	10.0%	10.0%	5.0%	5.0%	30.0%	5.0%	5.0%	5.0%	5.0%	100.0%	
Filtration, UV	Yes	Yes	Yes	-82.5%	98.8%	-81.8%	-17.5%	-0.9%	26%	14.8%	-10%	0%	0%	-7.8%	
Filtration, UV	Yes	Yes	Yes	-55.9%	100.0%	-65.7%	2.1%	10.6%	32%	14.8%	-5%	0%	10%	3.6%	
Filtration, UV	Yes	Yes	Yes	11.1%	100.0%	-89.4%	30.1%	//	23%	14.8%	-10%	0%	10%	//	
Filtration, UV	Yes	Yes	Yes	15.0%	100.0%	-58.7%	30.1%	-61.5%	35%	14.8%	-10%	0%	10%	16.8%	
Filtration, plasma arc shockwave, UV	Yes	Yes	Yes	//	//	//	//	//	//	-3.4%	-10%	0%	10%	//	
Filtration, chlorine dioxide injection	Yes	Yes	Yes	38.3%	100.0%	89.4%	30.1%	-0.9%	-168%	-21.0%	0%	0	10%	-23.4%	**3**
Filtration, sodium hypochlorite injection (stored), neutralization	Yes	Yes	Yes	26.7%	//	95.5%	30.1%	//	-77%	-17.6%	-10%	-10%	10%	//	**4**
Filtration, sodium hypochlorite injection (generated), neutralization	Yes	Yes	Yes	33.1%	0.0%	10.4%	30.1%	11.7%	-100%	-17.6%	-10%	-10%	10%	-21.5%	**4, 5**
Filtration, sodium hypochlorite injection (generated), neutralization	Yes	Yes	Yes	0.6%	0.0%	24.2%	30.1%	//	-66%	-1.4%	-10%	-10%	10%	//	**4, 5**
Filtration, cavitation, sodium hypochlorite injection (generated)	Yes	Yes	Yes	3.4%	0.0%	29.3%	2.1%	15.9%	-93%	14.8%	-10%	-5%	10%	-22.8%	**4, 5**
Hydrocyclone, electrolytic chlorination (in stream)	No	No	Yes	--	--	--	--	--	--	--	--	--	--	-	**4, 6**
Electrolytic advanced oxidation, neutralization	Yes	Yes	Yes	-0.9%	93.2%	-10.6%	72.0%	24.3%	55%	-31.5%	0%	-5%	10%	28.0%	
Filtration, advanced oxidation (via UV)	Yes	Yes	Yes	--	--	--	--	--	--	--	--	--	--	--	**7**
Filtration, advanced oxidation (via electrodes)	No	Yes	Yes	--	--	--	--	--	--	--	--	--	--	--	**8**
Filtration, advanced oxidation, ultrasonic (electrolytic)	Yes	Yes	Yes	76.6%	93.2%	22.7%	2.1%	//	//	-1.4%	-10%	0%	10%	//	
Ozonation, neutralization	Yes	Yes	Yes	22.7%	93.2%	-10.7%	0.0%	-26.2%	55%	-1.4%	0%	0%	0%	27.6%	
Cavitation, electrochlorination, ozone	Yes	No	Yes	14.4%	100.0%	77.3%	-39.9%	11.7%	91%	1.9%	0%	-5%	0%	-	**6**
Hydrodynamic shear, cavitation, ozonation	Yes	Yes	Yes	//	//	//	//	//	//	-17.6%	-10%	-5%	10%	//	
Cavitation, deoxygenation	Yes	Yes	No	--	--	--	--	--	--	--	--	--	--	//	**9**

General Scores in the quantitative and qualitative measures indicate the relative economic impact on vessel operations. Unless otherwise noted, each score represents a percent deviation from the average score for that criterion. Higher scores indicate lower cost or positive impact on operational cost; lower scores indicate the opposite. Positive values are based on the best operating condition and negative values are based on the worst operating conditions
.

-- Denotes a category that was not scored because the system did not meet efficacy criteria or was removed from consideration after by the project team discussion with vendor.
// Denotes information that was not available for inclusion in report.

Notes:
1 Operational complexity based on number of major system components and a small empirical adjustment for perceived machinery complexity.
2 Ballast rate effect is estimated based on net flow rate effect of filtration. Ranking is based on California State Lands Commission (August 2010).
3 Chlorine Dioxide must be held for 24 hours by regulation (State of Michigan Department of Environmental Quality, October 11, 2006).
4 Hypochlorite based systems to hold ballast for 19 hours with total residual oxidants (TRO) of 10 parts per million (ppm) by regulation (State of Michigan Department of Environmental Quality, October 11, 2006).
5 Consumable volume and Opex for Electrochlorination systems that require salt for operation in fresh water is estimated assuming 1 ton of salt is required per 3,785 m^3 of ballast processed at a cost of $150/ton.
6 In-stream electro-chlorination is not effective in low temperature water (Severn Trent De Nora, March 2011).
7 System removed from consideration after discussion with vendor.
8 System requires 1000 µS/cm conductivity to function effectively. Salinity in Duluth is about one quarter of this value, per Schloericke (June 7, 2011).
9 Deoxygenation requires 4-6 days hold time (American Bureau of Shipping, April 2011); 48 hours is required by regulation (State of Michigan Department of Environmental Quality, October 11, 2006).

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3.3 Technologies Selected

Based on the available information presented by manufacturers, 16 systems representing five primary technologies meet the three basic criteria for efficacy in fresh water with ambient water temperatures ranging from 0 ºC to 25 ºC, and required hold times of 24 hours or less. These technologies are:

1. Filtration/UV radiation.
2. Filtration/chlorine dioxide treatment.
3. Filtration/sodium hypochlorite treatment (in two variations).
4. Ozone.
5. Advanced oxidation.

In the analysis and discussion that follows, it is assumed that the individual systems would be effective in treating ballast water to comply with regulatory requirements. This study did not validate efficacy for any system.

3.3.1 Filtration/UV Radiation

Four different vendors offer UV systems. All operate by passing ballast water through an automatic back-flushing filter to remove larger organisms, followed by intense UV irradiation to render non-viable (incapable of reproduction) or sometimes kill the remaining organisms (depending on dose). The systems operate on ballast water uptake and discharge. The primary benefits to UV systems are they are simple to operate, need no consumables, and are claimed to not require extensive ballast water hold time prior to discharge to allow for degradation of residual biocide. Other characteristics are:

1. Power Consumption: Power consumption is approximately 71 kWh/1000 m^3.
2. System Footprint: The system footprint is between 30 and 50 m^2 for a system capable of 6000 m^3/hr ballast flow, depending on vendor.
3. Hold Time: Treatment occurs simultaneously with ballast water intake, but while there is no need for degradation of residual biocide over time, there is often a delay in the mortality effect, as UV, at the intensities used, isn't so much immediately fatal as destructive of DNA. There can be a significant lag before death, if death occurs at all. The second UV irradiation on discharge is intended to act on any surviving organisms.
4. Consumables: None. Note: The study categorized “consumables” as material or chemical additives that required replenishment or replacing every use.
5. Operational and Maintenance Cost: Cost is approximately $20/1000 m^3 of ballast processed (Lloyds Register, February 2010).

3.3.2 Filtration/Chlorine Dioxide Treatment

At the time of this study, only one vendor offered a BWT system based on this combination of technologies. The system operates by dosing pre-filtered ballast water with chlorine dioxide, which is prepared onboard from two feed chemicals. The modular nature of this chlorine dioxide system offers flexibility of equipment installation arrangements. The primary downside of the chlorine dioxide-based system is the high cost of feed chemicals. Other characteristics are:

1. Power Consumption: Power consumption is about 6.5 kWh/1000 m^3.
2. System Footprint: The system footprint is approximately 20 m^2 for a 6000 m^3/hr system.
3. Hold Time: 24 hours prior to discharge. The system will not be suitable for some vessels due to extended hold time requirement (Lloyds Register, February 2010; State of Michigan Department of Environmental Quality, October 11, 2006).

4. Consumables: This requires two feed chemicals, Purate and sulfuric acid.
5. Operational and Maintenance Cost: Estimated operating and maintenance cost is $80/1000 m^3 of ballast processed (Lloyds Register, February 2010).

3.3.3 Filtration/Sodium Hypochlorite Treatment

3.3.3.1 Treatment with Sodium Hypochlorite Stored in Tanks

One vendor offers this BWT arrangement. This arrangement consists of a sodium hypochlorite solution from a storage tank injected into the ballast stream, following a filtration stage. A neutralizing chemical introduced in the ballast stream eliminates residual chlorine on discharge. Other characteristics are:

1. Power Consumption: Power consumption is about 3 kWh/1000m^3.
2. System Footprint: Based on listed sizes of smaller systems, estimated footprint for a 6000 m^3/hr system is 24 m^2 (Lloyds Register, February 2010).
3. Hold Time: Required ballast water hold time is 9 to 24 hours (State of Michigan Department of Environmental Quality, October 11, 2006; Li, June 12, 2011). The system will not be suitable for some vessels due to length of hold time required.
4. Consumables: This includes a sodium hypochlorite solution.
5. Operational and Maintenance Cost; Cost is approximately $50/1000 m^3 of ballast water processed.

3.3.3.2 Treatment with Sodium Hypochlorite, Onboard Generation

Two vendors offer this technology. Both vendors include a filtration stage prior to injection of a sodium hypochlorite solution into the ballast stream. This arrangement consists of sodium hypochlorite generated onboard by electrolyzing a small portion of the ballast water flow. In fresh water, salt added to this side stream raises salinity prior to electrolysis, and the feed water must be preheated when the ballast water temperatures drop below 15 ºC.

1. Power Consumption: Power requirements are about 59 kWh/1000 m^3 of ballast processed.
2. System Footprint: System footprint is about 27 m^2 for a system capable of treating 6000 m^3/hr.
3. Hold Time: Required ballast water hold time is 9 to 24 hours (State of Michigan Department of Environmental Quality, October 11, 2006; Li, June 12, 2011).
4. Consumables: Salt or salt brine, neutralizer.
5. Operational and Maintenance Cost: Operating cost is approximately $60/1000 m^3. Estimated cost includes added cost of salt for operation in fresh water.

3.3.4 Ozone

Three BWT system vendors use ozone technology. Ozone generated onboard mixes with the incoming ballast water. Two vendors combine ozone treatment with other technologies, including hydrodynamic shear, cavitation, and electro-chlorination. One vendor uses ozone exclusively and provides neutralization. Other characteristics are:

1. Power Consumption: Power requirements for a pure ozone system are about 73 kWh/1000 m^3 of ballast water treated.
2. System Footprint: The system footprint for a system capable of treating 6000 m^3/hr is approximately 25 m^2. Ozone-generation equipment can be located remotely, providing some additional flexibility in installation.
3. Hold Time: Available reports indicate neutralization will be required for successful application of ozone in fresh water if ballast retention times under 24 hours are required (Cangelosi, November 12, 2010; Ballast Water Working Group, April 8, 2009).

4. Consumables: Neutralizer.
5. Operational and Maintenance Cost: The Lloyds Register (February 2010) lists estimated operation and maintenance costs of \$7/1000 m^3 for a pure ozone system. The estimated cost of power alone would be approximately \$14/1000 m^3 electrical consumption to operate the system. The total cost for a standalone system would be \$21/1000 m^3. The operation and maintenance of the electrical power may decrease if it is part of the existing ship's electrical generator power.

3.3.5 Advanced Oxidation

Four BWT system vendors use advanced oxidation technology; two have indicated their systems operate effectively in fresh water. The two systems use an electrolysis unit capable of generating hydroxyl radicals and oxidants directly in the ballast stream.

1. Power Consumption: Power requirements of the systems vary. One vendor lists 73 kWh/1000 m^3 of ballast water treated. Another indicated 36 kWh/1000 m^3 would be required.
2. System Footprint: Vendor-provided footprint estimates were not readily available. System components require approximately 8-10 m^2. With piping, the installed system footprint is anticipated to be 15-25 m^2.
3. Hold Time: Vendor information indicates ballast retention times under 24 hours are acceptable with addition of a neutralization system (Techcross, February 2011; Michalak, June 20, 2011).
4. Consumables: Neutralizer.
5. Operational and Maintenance Cost: The cost of power required to supply the units primarily drive operation and maintenance costs. The Lloyds Register (February 2010) lists operation and maintenance costs of approximately \$3/1000 m^3 of ballast water treated. The estimated cost of power would be approximately \$7/1000 m^3 to \$14/1000 m^3 electrical consumption to operate the system. The total cost for a stand-alone system would be \$10/1000 m^3 to \$17/1000 m^3. The operation and maintenance of the electrical power may decrease if it is part of the existing ship's electrical generator power. Electrical requirements in freshwater are three times those reported in salt water according to vendors (Techcross, February 2011; Michalak, June 20, 2011).

3.4 Final Technologies Selected

Based on the limited information available for this study as discussed above and as listed in Table 3, including reliance on vendor-provided information, and assuming all technologies will be effective in meeting treatment regulatory requirements, BWT technologies likely to provide a good overall return on investment are filtration/UV (Table 3 weighted score of 16.8%), ozone (27.6%), and advanced oxidation (28%). Using the methods described above, these technologies showed the lowest operating and maintenance costs, and similar electrical requirements. The chlorine dioxide- and sodium hypochlorite-based systems are attractive in terms of electrical requirements, but the variability associated with estimating the cost of consumables, discharge permits, and storage over the long term led the project to not investigate further. Because of this "consumables" issue, the project decided to investigate only the filtration/UV and ozone technologies for vessel installation. In fact, the project encourages further examination of active-substance technologies that rely on consumables.

Requests for technical information went to vendors of the selected systems. Broad, order-of-magnitude indicators of cost, practicability, and previous testing in fresh water assisted in technology selection. The ability to obtain reliable engineering and design information also drove selection, as to provide the most accurate design modification to the selected vessels. ***Selection of technologies for this practicability study does not represent a recommendation of these technologies or specific systems over others for a specific***

vessel application. Variations in equipment, arrangement, and operations from vessel-to-vessel are significant, and were not considered. As stated earlier, the study did not actually test systems. The information here does not eliminate the need for full, vessel-specific analysis, including system testing in conditions similar to those found in the Great Lakes, and testing for compliance with USCG regulations.

3.4.1 Filtration/UV System Operation

The first selected system is a filtration/UV system. The following sequence occurs when taking on ballast water. The ballast pumps take water from the sea chests. The raw water passes through the ballast pumps and into the BWT systems, which are installed downstream of each pump. The ballast water passes through the filter assembly first, and then through the UV reactor. Finally, the treated ballast water moves on to the ballast tanks.

During ballasting, the system cleans individual filter units as they fill up with particulates and organisms greater than 50 μ in size. The system isolates the filter unit and triggers the back-flush pump to reverse flow in the unit and clean out the filters. This back-flush water travels through a drain line and goes overboard via separate sea chests, into the same water from where it came. (Note: The drain line will require flushing or treatment to prevent organisms from being moved between locations in residual water remaining in the line during transit.) After filter cleaning completes, the filter switches back to normal operation. Cleaning one filter unit at a time in this manner does not significantly reduce system capacity and ensures long filter life. After ballasting, a complete back flush of the filters must take place to ensure no invasive species remain in the ballast piping, thus leaving the potential to transport and deposit them in a different port.

The following sequence occurs to discharge ballast water. The pump draws water from the ballast tank and pumps it through the BWT system. During discharge, the control system bypasses the filter assembly automatically. The ballast water passes through the UV reactor, which irradiates any organisms that may have survived the initial treatment on uptake. Ballast water then discharges directly overboard through a sea chest.

3.4.2 Ozone System Operation

The second selected system is an ozone injection system. The system operates as follows when taking on ballast water. The system extracts oxygen from a supply of compressed air and converts some of that oxygen into ozone. This ozone/oxygen mixture travels to ozone injectors, which dissolve the ozone into a small supply of raw ballast water. The system distributes this ozonated water to the main ballast system, where it mixes with the full ballast water flow. A total residual oxidant sensor in the ballast line controls the ozonated-water flow to provide the correct dose of ozone, based on the oxidant demand of the water (the demand is a function of the amount of organic material, including living, dead, particulate and dissolved, in the water).

The system has several auxiliary components that support its continuous operation. The ozone generator works at full capacity any time ozone is required; i.e., during ballasting. Because of this, the system requires a vent and ozone destruct unit to release any excess ozone that the system generates beyond what the ballast water requires. The system also requires a vent from the oxygen generators to release the other atmospheric gasses removed from the compressed air when extracting the oxygen. Finally, the system must have a circulating supply of chilled water to keep the ozone generator operating at the correct temperature. This requires one or more chiller units, which need a supply of lake water to absorb the excess heat.

4 EXAMPLE VESSEL INSTALLATIONS

4.1 Vessel One: Intermediate to Large 1000' Laker

4.1.1 Vessel One: Vessel Description

Vessel One is a Great Lakes intermediate to large capacity, self-unloading bulk carrier built in 1978 at American Ship Building Company. The vessel has been operating on the Great Lakes for 32 years. Drawings of the vessel are in Volume I, Appendix A of this report. Table 4 lists the principal characteristics.

Table 4. Vessel One particulars.

Length at Waterline	1,000.0'
Beam Molded	105.0'
Draft	28'
Depth, Molded, Main Deck	50.0'
Camber of Main Deck, Straight Line	0.5' in 52.5'
Lightship	13,389 lt
Gross Tonnage	34,568
Net Tonnage (Registered)	29,412
Number of Cargo Holds	14
Cargo Type	Iron Ore Pellets
Deadweight Tonnage	62,400 lt (63,401 mt)
Number of Ballast Tanks	20
Ballast Tank Capacity	34,569 mt
Power Plant	16,000 hp (Diesel)
Year Built	1978
Shipyard	American Ship Building Co.

The vessel arrangement has a deckhouse aft with accommodations and propulsion located at the extreme aft. A self-unloading system is at the aft end of the cargo block, embedded into the machinery space both below the main deck and into the deckhouse above the main deck. The machinery space is 42.0' long. The nine cargo holds are comprised of a series of sloped hoppers in a "hogsback" configuration feeding gravity cargo gates. (Note: The hogsback hopper configuration refers to the structural arrangements at the bottom of each of the cargo hoppers. The structural arrangements and separations provide for a uniform flow of cargo onto the conveyor belts, and resemble the raised "bumps" or folds on a hog's back.) From the gates, the cargo flows onto longitudinal, port and starboard conveyor belts. These conveyor belts feed the off-loading conveyor belt and unloader. For loading the vessel, the main deck has 36 hatches with covers. A hatch cover crane removes and stacks the hatch covers.

The installed ballast system is capable of counter-acting the loading rate of a shore facility to keep the vessel in close vertical tolerance to the loading facility. There are 20 ballast tanks total; consisting of one forepeak tank, nine pairs of port and starboard wing tanks, and one afterpeak tank. The ballast system is comprised of 18 electric motor driven pumps, with a capacity of 3,600 gallons per minute (gpm) (817.65 m^3/hr) each (64,800 gpm/14,718 m^3/hr total). The ballast piping system on this 1000' vessel is a series of discrete, distributed systems with one ballast pump for each wing tank, except for the forward port system, which handles both the #1 port and the forepeak ballast tank.

4.1.2 Vessel One BWT System 1: Filtration and UV

4.1.2.1 Vessel One BWT System 1: General

The first BWT system considered for Vessel One is a filtration and UV treatment system. Section 3.4.1 contains a description of the filtration and UV system. The vessel requires 18 complete BWT systems total, one for each ballast system. The vessel has a BWT system (filters, back-flush pump, UV reactor, sensors, power and control units, etc.) and piping, sized for each ballast pump, and installed in the centerline void underneath the cargo hold's hopper configuration. Each of the discrete BWT systems sits as near as possible to the ballast system it services. The forward-port system services the forepeak tank, and the aft-starboard system services the aft peak tank.

Each complete BWT system has the following components.

1. One filtration assembly.
2. One UV reactor.
3. One back-flush pump.
4. One power supply cabinet for the UV reactor.
5. One power supply cabinet for the back-flush pump.
6. One control panel to operate the whole system.

4.1.2.2 Vessel One BWT System 1: BWT System Arrangement

The naval architects and marine engineers for this study determined that the most economical approach for this vessel was to install 18 individual BWT systems. (See **Appendix A**, Figure A-1). The BWT systems are fit inboard of the ballast pumps and conveyors, to port or starboard of centerline, under the tallest portion of the hogsback/cargo hopper structure. The centerline void has a clear transverse distance of 9.33' to port or starboard of the centerline stanchion. The height below the web frames is 15' high at centerline and 7.5' high at the outboard extent. The installed BWT system requires most of the clear space, and the largest component is the filter assembly. Routing the pipes from the ballast pump across to the BWT system and back to the ballast tanks adds some difficulty to the arrangement. In addition, the component locations selected ensure adequate clearances for maintenance for all equipment involved. The filter assembly and UV reactor are in line with each other to simplify piping connections.

All 18 BWT systems follow the arrangement listed above. Because of the extensive length of the space, placement of the systems and their controls is flexible. Adjacent port and starboard systems are staggered throughout the length of the vessel. This maintains a clear path throughout the length of this space.

4.1.2.3 Vessel One BWT System 1: Structural Changes

Installation of the BWT systems requires the following structural additions.

1. Provide foundations for all components of all 18 BWT systems. Each system includes a filter assembly, UV reactor, back-flush pump, system control panel, UV power panel, and back-flush pump control.
2. Mount piping for all systems to adjacent structure as necessary.
3. Modify bottom structure to add three new sea chests total. Sea chests are to be central to groups of six BWT systems and provide an outlet for those BWT system's back-flush drains.

Two new generators are necessary to supplement the existing electrical system to be able to power all of the ballast pumps and BWT systems at once. The vessel drawings are not detailed enough to prove whether the generators can fit in the machinery space. Therefore, the installation uses enclosures for the generators

placed on a suitable location on the deckhouse. The following are the preliminary and estimated structural additions required to support installation of the new generators.

1. Reconfigure a location on the deckhouse to fit the new generator enclosures.
2. Install new supports and foundations for two generator enclosures.

4.1.2.4 Vessel One BWT System 1: Mechanical Modifications

The material schedule and piping diagram as shown in Appendix A, Figure A-1. Installing the BWT systems in the centerline void requires several new mechanical systems in the space. The following system modifications ensure proper and safe operation of all BWT systems.

1. New or larger compartment ventilation systems may be necessary. This would include a watertight bulkhead penetration to prevent progressive flooding. It also requires a fire damper because the ventilation ducting goes from the new machinery space aft into the engine room.
2. New fire protection systems. The current arrangement should only require fire extinguishers (Code of Federal Regulations - 46 CFR 95.50, 2011; Code of Federal Regulations - 46 CFR 95.05-10, 2011).

The BWT systems also require several forms of supporting machinery and ship services. Each component has to be installed along with the supporting ship's systems. The following list is the hardware and system installed or modified.

1. Install 18 BWT filter assemblies.
2. Install 18 BWT UV reactors.
3. Install a back-flush pump for each BWT system (18 total).
4. Supply pressurized air to BWT system for pneumatic control valves. The BWT control system activates the valves, while the ship's supply air powers their actuation.
5. Remove or reconfigure a section of existing 10" ballast piping to accommodate connection of new BWT system piping.
6. Install new 10" pipes to connect the BWT system into the existing ballast systems.
7. Install new 5" drain piping for the back-flush connection from each BWT system, including a check valve for each drain connection.
8. Install three new sea chests for the back-flush drain piping.
9. Install new 8" common drain-line connecting drains from each BWT system to the nearest sea chest, including a gate valve to isolate the sea chest.
10. Install storage cabinets to hold spare parts and tools for maintenance of BWT system.

Each of these new mechanical systems may interfere with existing systems and ship's structure. The installation anticipates some amount of minor relocation may be necessary. Installation of the large mechanical systems likely requires removal of the cargo hold bottom plating to gain access to the centerline void. Installation will require ship drydocking and extensive shipyard work.

New supplemental generators installed in enclosures mounted on the deckhouse will meet the new electrical requirements. Several new mechanical systems are required to support the generators. The following list may be incomplete or need updating pending detailed electrical information from the vessel.

1. Install one new enclosure on each side of the vessel for supplemental BWT supply generators (two new enclosures total). Enclosures must have A60-rated structural fire protection.
2. Install one new BWT supplemental generator on each side of the vessel (two generators total). Generator is located inside the new enclosure. Each generator supplies 910 electrical kilowatts (ekW) of power (1820 ekW total). An example of a suitable generator is the Caterpillar C32 ACERT, generator.
3. Install fuel transfer lines and valves from the main fuel system to the two new supplemental generators.
4. Install self-contained CO2 fire suppression systems for each of the new supplemental generators (two new systems total).
5. Install fuel tanks for each new supplemental generator (two new tanks total, each with the capacity to allow at least 24 hours of continuous generator operation, under full power load conditions). Day tanks are located in the enclosure along with the generator. Tanks must have A60-rated structural fire protection.

4.1.2.5 Vessel One BWT System 1: Electrical Modifications

The project did not complete an electrical loads analysis for the vessel. Instead, as a conservative estimate, the project assumes no spare electrical capacity.

The BWT system requires significant electrical additions. The largest power requirement comes from the UV reactors. The total possible additional power requirement when all of the new BWT systems and back-flush pumps are operating is 1816 kW (Appendix A, Table A-1). However, it is highly unlikely that all 18 systems will back-flush simultaneously. To meet the new electrical load requirement, the vessel will have two new supplemental generators, each rated at 910 ekW. During ballasting operations, all of the vessel generators will operate in parallel.

There are also several other supporting installations required. The following electrical additions are necessary.

1. Install 18 vendor-supplied system control panels. Power supply to panel must be 240 V, single-phase, 60-Hz.
2. Install 18 vendor-supplied UV reactor power panels. Power supply to panels must be 440 V, 3-phase, 60-Hz.
3. Install 18 vendor-supplied power panels for the back-flush pumps. Power supply to panels must be 440 V, 3-phase, 60-Hz.
4. Install power switchboard for each BWT supplemental generator. Switchboard is located in the same enclosure with the supplemental generator (two switchboards total).
5. Install cross-connection between each BWT supplemental generator and between existing ship service generators. Cross-connection must include wiring for 440 V, 3-phase, 60-Hz, 7.50 A per phase. Include necessary equipment to run parallel between supplemental generators and ship service generators.
6. Install wiring for serial communication between BWT system and the ship's ballast management system.
7. Install wiring and lighting receptacles within the centerline space.

4.1.2.6 Vessel One BWT System 1: Control System Integration

4.1.2.6.1 Control Systems Considered for Installation

The BWT systems are self-contained, stand-alone treatment plants. The control system do not require input from any outside devices other than to turn it on and off. The goal is to have the system completely integrated into the ship's control/monitoring system. The advantages of this are that there will be no need to have additional panels in control areas, and the entire process can be monitored from the same screens the crew uses to monitor/control the rest of the ship. There are two main ways to achieve the control integration. The first and most basic are hard wiring inputs and outputs. The second and most informative technique is through serial communication.

With hard wiring, there is one wire for every desired signal from the BWT control panel to the ship's control/monitoring system. This allows basic control to start and stop the BWT system. The system also returns basic outputs of run/stop/alarm. The advantages for this type of integration are that it is very straightforward and there are no communication issues. The hard-wire system requires running multiple cables, one for each monitoring/control signal. This is a disadvantage to large distributed systems.

With serial communication, the BWT control system communicates with other control systems via a serial interface. The physical installation of this scheme is one telemetry cable from the BWT monitoring/control to the ship's monitoring/control system. Once the communication is set up, the ship's control system monitors every aspect of the BWT system's operation. This lets the ship's monitoring system log all of the required data for the ballast water log book. Serial integration does take more up-front interaction between the ship's control system provider and BWT system vendor.

4.1.2.6.2 Vessel One BWT System 1: Control System Integration

The BWT system for Vessel One has 18 individual systems. A monitoring/control signal from each system needs to be integrated into the ship's control system. Serial communication reduces the number of telemetry cables required to safely integrate the BWT monitoring/control system. The hard-wire system would require a telemetry cable for each monitored/control signal. This would result in a large telemetry cable. The serial system reduces the size of the telemetry cable resulting in less cable and reduced installation costs. The project recommends a serial system.

4.1.2.7 Vessel One BWT System 1: Operational Impacts

The added weight to install BWT system increases the lightship weight. This results in a decrease in deadweight and cargo capacity of 102 lt, (see Appendix A, Table A-2). This is a estimated decrease of 0.16 percent in cargo capacity.

4.1.2.8 Vessel One BWT System 1: Estimated Costs and Schedule Impact

The cost and schedule estimate for the installation of filtration and UV reactor ballast systems in the intermediate to large capacity 1000' Great Lakes bulk carrier is based on labor hours and material and subcontractor costs from estimating data gathered from shipyards for this type of work and budget quotes from vendors and subcontractors. The estimate assumes that the installations would be done during the annual winter layup. Work required that involves the hull underbody would be scheduled while the ship is in drydock.

The cost and schedule estimate is based on a concept design, so labor hours and material and subcontractor costs are given a 12 percent margin. An 18 percent contingency is applied to the final cost. The margins and contingencies are based on data from Naval Sea Systems Command (August 2011). The total estimated cost for the installation of filtration and UV reactor-type BWT systems in the intermediate to large capacity 1000’ Laker is $10,951,000 and will take 17 weeks with an average manning of 70 people; see Appendix A, Table A-3.

4.1.3 Vessel One BWT System 2: Ozone

4.1.3.1 Vessel One BWT System 2: General

The second BWT system considered for Vessel One is an ozone injection system. Section 3.4.2 contains a basic description of the operation of the system; however, there are some differences for Vessel One. The system generates ozone in the same manner, but the distribution system is different in order to service the many discrete ballast systems. From the ozone generators, the ozone/oxygen mixture travels outboard to the ozone injectors, which dissolve the ozone into a supply of raw ballast water from their nearest sea chests; see Appendix A, Figure A-2. This ozonated-water then travels out to each of the ballast systems through an ozonated-water header, where it mixes with the ballast water at each individual ballast system.

The vessel requires one complete ozone system (compressors, oxygen generators, receivers, ozone generator, and chillers), which supplies ozone for all 20 ballast tanks on the vessel. The ozone generation equipment all fits in the centerline void underneath the cargo holds’ hogsback hopper configuration. The port and starboard injector systems sit directly outboard of the ozone generator to minimize the length of ozone piping. The vessel has 19 injection sections installed total; one for each of the 18 ballast systems on the vessel, and one for the fire and general service system that fills the aft peak ballast tank. The lightship weight increases by 100 lt; see Appendix A, Table A-5.

4.1.3.2 Vessel One BWT System 2: BWT System Arrangement

The components of the ozone generation system mount within the centerline void, inboard of the ballast pumps and conveyors, under the tallest portion of the hogsback/cargo hopper structure; see Appendix A, Figure A-2. In this area, the height below the web frames is 15’ high at centerline and 7.5’ high at the outboard extent. The various installed systems require most of the clear height or width available. The oxygen generators and receivers only fit on centerline because of their height. The compressors, ozone generators, control panels, and chillers sit to one side of centerline to avoid the stanchions and to ensure adequate clearance for maintenance.

The chillers used to cool the ozone generator require a constant supply of water. A supply pipe runs from the sea chest for ballast tank #5 port to the chillers. The discharge line runs to the opposite sea chest (#5 starboard) to prevent recirculation of heated water through the chiller units.

Longitudinally, the ozone generator sits beneath cargo hold #4, which is the middle hold on the vessel. Installing the ozone generator near midship minimizes the length of the ozone and ozonated-water distribution piping to limit the breakdown of the ozone before it enters the tanks. Upon exiting the ozone generator, the ozone travels to the port and starboard ozone injectors, outboard of the ozone generator. The ozone injector system consists of a pump that draws water from a sea chest and pumps it through an ozone injector, which dissolves the ozone into a supply of raw water.

The ozonated-water then travels down port and starboard distribution headers, from which a branch delivers it to each ballast system. The individual branches consist of an injection section that combines the ozonated-water with the ballast water before it enters the tank. A sensor for each tank, measuring total residual oxidants, regulates the flow of ozonated-water into the ballast water. All 19 ballast systems use this branch arrangement.

4.1.3.3 Vessel One BWT System 2: Structural Changes

Installation of the BWT systems requires the following structural additions.

1. Provide foundations for BWT system components. This includes ozone generators, power and control panels, air compressors, receivers, oxygen generators, and chillers.
2. Mount piping to adjacent structure as necessary.

The following are the preliminary and estimated structural additions required to support installation of the new generators. The new generators are necessary to supplement the existing electrical system to be able to power all of the ballast pumps and BWT systems at once.

1. Reconfigure two locations on the deckhouse to fit the new generator enclosures.
2. Install new supports and foundations for two generator enclosures.

4.1.3.4 Vessel One BWT System 2: Mechanical Modifications

Adding the BWT systems to the centerline void may require several new mechanical systems in the space. Installing the following systems ensures safe and proper operation of all the BWT systems.

1. Install new ventilation system capable of providing 48,000 cubic feet per minute (cfm) of air to the centerline void. Two 42” Hartzell Series 46 fans are a possible choice to provide sufficient air capacity.
2. The ventilation system will include ducting runs that come down through the exhaust casing and the machinery space before passing forward into the centerline void to which it supplies air.
3. The ventilation installation includes a watertight bulkhead penetration to prevent progressive flooding and a fire damper because the ventilation ducting goes from the new machinery space aft into the engine room.
4. New fire protection systems. The current arrangement should only require fire extinguishers (Code of Federal Regulations - 46 CFR 95.50, 2011; Code of Federal Regulations - 46 CFR 95.05-10, 2011).

The ozone system is supplied as several separate components. Each component has to be installed along with the supporting ship’s systems. The following list is the hardware and system installed or modified.

1. Install two air compressors.
2. Install two compressed air receivers.
3. Install two oxygen generators.
4. Install two oxygen receivers.
5. Install one ozone generator and its power/control panel and high voltage transformer.
6. Install two chiller units and condenser water pumps.
7. Install new 1.5” and 2” air/oxygen supply system piping.
8. Install new 2” nitrogen vent and ozone vent/destruct piping.
9. Install new 3” chiller supply, drain, and recirculation pipes.

10. Install new 2” pipes to distribute ozone to the ozone injector pumps.
11. Install new 4” ozone injector pump supply pipe.
12. Install new 3” ozonated-water piping and delivery headers.
13. Install new 1.5” ozonated-water branch piping for each injection section.
14. Install 19 ozonated-water injection sections.
15. Extend 19 ballast tank inlets (10” pipes) to accommodate the injection section and sensors.
16. Install storage cabinets to hold spare parts and tools for maintenance of BWT system.

Each of these new mechanical systems may interfere with existing systems and ship’s structure. The installation anticipates some amount of minor relocation may be necessary. Installation of the large mechanical systems likely requires removal of the cargo hold bottom plating to gain access to the centerline void. Installation will likely require ship drydocking and extensive shipyard work.

Two new supplemental generators installed in enclosures on the deckhouse will meet the new electrical requirements. Several new mechanical systems are required to support the generators. This list may be incomplete or need updating pending detailed electrical information from the vessel.

1. Install one new enclosure on each side of the vessel for supplemental BWT supply generators (two new enclosures total). Enclosures must have A60-rated structural fire protection.
2. Install one new BWT supplemental generator on each side of the vessel (two generators total). Generator is located inside the new enclosure. Each generator supplies 715 ekW of power (1,430 ekW total). An example of a suitable generator is the Caterpillar C32 ACERT generator.
3. Install fuel transfer lines and valves from the main fuel system to the two new supplemental generators.
4. Install self-contained CO2 fire suppression systems for each of the new supplemental generators (two new systems total).
5. Install fuel tanks for each new supplemental generator (two new tanks total, each with the capacity to allow at least 24 hours of continuous generator operation, under full power load conditions). Day tanks are located in the enclosure along with the generator. Tanks must have A60-rated structural fire protection.

4.1.3.5 Vessel One BWT System 2: Electrical Modifications

As in Section 4.1.2.5the project assumes no spare electrical capacity. Based on the electrical requirements of the ozone systems, the total additional power requirement when all ozone generation equipment and injection pumps are operating is 1386 kW (Appendix A, Table A-4). Two supplemental generators, each rated at approximately 715 ekW, provide the required additional power. During ballasting operations, all of the vessel’s generators will operate in parallel to provide the required power.

There are also several other supporting installations required. The following electrical additions are necessary.

1. Install vendor-supplied power panel and high voltage transformer for the ozone generator. Power supply to panel must be 480 V, 60-Hz, 3-phase power capable of supplying 370 kW.
2. Install two motor controllers for the ozone injection pumps. Power supply must be 460 V, 3-phase, 60-Hz.
3. Install two motor controllers for the chiller water pumps. Power supply must be 460 V, 3-phase, 60-Hz.
4. Install 460 V, 3-phase, 60-Hz wiring for the air compressors.

5. Install 120 V, 1-phase, 60-Hz wiring for the oxygen generators.
6. Install 460 V, 3-phase, 60-Hz wiring for the chiller units.
7. Install power switchboard for each BWT supplemental generator. Switchboard is located in the same enclosure with the supplemental generator (two switchboards total).
8. Install cross-connection between each BWT supplemental generator and between existing ship service generators. Cross-connection must include wiring for 440 V, 3-phase, 60-Hz, 7.50 A per phase. Include necessary equipment to run parallel between supplemental generators and ship service generators.
9. Install wiring between BWT system and the ship's ballast management system.

4.1.3.6 Vessel One BWT System 2: Control System Integration

The ozone generator needs to run continuously during ballasting, but not during deballasting. The operator must turn on the ozone generator before ballasting begins, and the two ozone injection pumps must run in parallel with the ballast pumps that they are servicing. In addition to the ozone generator, there are several auxiliary components that must work together seamlessly for the whole system to run properly. The compressors and oxygen generators automatically supply the receivers, keeping them filled to a set level. The ozone generator runs the chiller units as necessary.

Section 4.1.2.6.1 provides an overview of the two different control systems that are being considered. The BWT system for Vessel One has 18 individual systems. A monitoring/control signal from each system needs to be integrated into the ship's control system. Serial communication reduces the number of telemetry cables required to safely integrate the BWT monitoring/control system. The hard-wire system would require a telemetry cable for each monitored/control signal. This would result in a large telemetry cable. The serial system reduces the size of the telemetry cable resulting in less cable and reduced installation costs. The project recommends a serial system.

4.1.3.7 Vessel One BWT System 2: Operational Impacts

The additional weight from installing the ozone BWT system reduces the total cargo capacity of the vessel. (See Appendix A, Table A-5 for design calculations.) Total estimated lost capacity is approximately 100.2 lt (0.16 percent of total cargo capacity).

4.1.3.8 Vessel One BWT System 2: Estimated Costs and Schedule Impact

The engineering, on which the estimate is based, is at a concept design level; labor, material, and subcontractor margins of 12 percent have been used in the SWBS sections. The total cost contains an 18 percent contingency. The margins and contingencies are based on data from Naval Sea Systems Command (August 2011). The total estimated cost for installation of an ozone-type BWT system in the intermediate to large capacity 1000' Laker is $7,731,190 and will take 20 weeks with an average manning level of 40 people. (See **Appendix A**, Table A-6).

4.2 Vessel Two: Large Capacity 1000' Laker

4.2.1 Vessel Two: Vessel Description

Vessel Two is a Great Lakes large capacity, self-unloading, bulk carrier built in 1979 at Bay Shipbuilding Company. The vessel has been operating on the Great Lakes for 32 years. Drawings of the vessel are in Volume I of this report. Table 5 lists the principal characteristics.

Table 5. Vessel Two particulars.

Length at Waterline	1,000.0’
Beam Molded	105.0’
Draft	34,0’
Depth, Molded, Main Deck	60.0’
Camber of Main Deck, Straight Line	1.09’ in 52.5’
Lightship	13,389 lt
Gross Tonnage	35,923
Net Tonnage (Registered)	33,534
Number of Cargo Holds	7
Cargo Type	Iron Ore Pellets, Coal
Deadweight Tonnage	89,641 lt (91,079 mt)
Number of Ballast Tanks	18
Ballast Tank Capacity	62,150 mt
Power Plant	16,000 hp (Diesel)
Year Built	1979
Shipyard	Bay Shipbuilding Company

The vessel arrangement has a deckhouse aft with accommodations and propulsion located at the extreme aft. It has a self-unloading system fitted at the aft end of the cargo block and embedded into the machinery space below the main deck and into the deckhouse above the main deck. The main engine space is 56.0’ (17.1 m) long. The seven cargo holds are comprised of transverse slopes feeding gravity-type cargo gates, where the cargo flows onto a single conveyor belt, which feeds the off-loading conveyor and swiveling boom, called the unloader. The main deck has 37 hatches; a hatch cover crane removes the hatch covers. The vessel can accommodate a loading rate of 10,000 long tons (lt) per hour (10,160 mt per hour).

The ballast system maintains the trim and list of the vessel during loading and unloading operations. The original ballast system is comprised of 14 ballast tanks aligned port and starboard, forepeak tank, port and starboard tanks aft, and an afterpeak tank. There are two large electric motor-driven pumps on each side of the vessel (four total), with a combined capacity of 52,000 gpm (11,810 m^3/hr) (13,000 gpm (2953 m^3/hr) each). The ballast piping system on the 1000’ vessel is a header leading down each side of the vessel and located in the ballast tanks with branch lines to each tank. Each main header is a 30” diameter pipe for the most of the length that tapers to a 16” diameter at the forward extreme, and the forepeak tank. The vessel also has a stripping system on each side, with a pumping capacity of 3,000 gpm (681 m^3/hr) each.

4.2.2 Vessel Two BWT System 1: Filtration and UV

4.2.2.1 Vessel Two BWT System 1: General

BWT System 1 for Vessel Two is a filtration and UV treatment system. Section 3.4.1 contains a description of the filtration and UV system. The vessel will have two complete BWT systems. The vessel BWT system consists of filters, back-flush pump, UV reactor, sensors, and power and control units. The BWT is sized to handle the water for the existing ballast systems. The BWT systems will be installed in converted ballast tank 7, port and starboard.

Each complete BWT system has the following components.

1. One filtration assembly.
2. One UV reactor.

3. One back-flush pump.
4. One power supply cabinet for the UV reactor.
5. One power supply cabinet for the back-flush pump.
6. One control panel to operate the whole system.

4.2.2.2 Vessel Two BWT System 1: BWT System Arrangement

There are two BWT systems, one starboard and one port; see Appendix B, Figure B-1. The port BWT system is the same, but opposite hand. The two systems are independent from each other, however an existing cross-connect remains in place.

Ideally, the best BWT installation location for this vessel is in the main engine room, but the engine room has insufficient space. A new machinery space is required to install the BWT systems, as each of these BWT systems is roughly the same size as the main engine, with the filter assembly alone measuring 26' (7.9 m) long x 13' (4.0 m) wide. The port and starboard number seven ballast tanks convert to new machinery spaces to accommodate the BWT system. The number seven ballast tank is 48' (14.6 m) long x 42.5' (13.0 m) wide. It has a sloped overhead that is 12.5' (3.8 m) above the bottom shell at the lowest point.

The largest component of the BWT system is the filter assembly and the best position for alignment with existing ballast pumps is as far inboard as possible. Height clearances for maintenance require a location in the transverse center of the compartment. The UV reactors are outboard of the filter assembly. The 30" diameter ballast water pipes are the second largest component. The BWT system is essentially installed downstream of the ballast water pump discharge. This arrangement allows the pumps to take suction on either the sea chest or the tanks. The piping routes to the outboard side of the space to allow clearance for the pipe to pass forward into the next compartment. The water from the sea chest feeds from the filter assembly to a large header, which leads into the UV reactors. All the UV reactors then feed into a second header and the ballast water travels back into the main ballast line. This line leads forward into the next compartment and moves back inboard to connect with the existing main ballast line. The stripping lines pump the water through the UV reactors in the opposite direction from normal operation, then overboard through a new discharge.

4.2.2.3 Vessel Two BWT System 1: Structural Changes

The following structural modifications (see Appendix B, Figure B-1) are required for each of the new machinery rooms.

1. Remove existing ballast system suction boxes in new machinery space.
2. Add floor at tank top level. This can be either grating or solid plating.
3. Remove and relocate any minor interferences.

The new BWT system requires supplemental diesel generators as the power draw is well in excess of the original electrical capacity. The most convenient location for these generators is on the 02 deck, attached to the aft bulkhead of the deckhouse. The air-cooled generators are installed as new self-contained modules, complete with voltage transformer, generator, fire suppression system, and enclosure. Existing vessel services will supply needed hotel power and fuel oil for generator operation. Exhaust from the generator vents through a muffler directly out of the aft side enclosure to the atmosphere. The following structural additions are required to support installation of the new supplemental BWT generators.

1. Cut back grating platform 02 deck on aft side of the deckhouse.
2. Install new supports and foundations for two self-enclosed generators.

3. Relocate doors to galley farther inboard.
4. Relocate any furnishing and arrangements inside galley to accommodate new door positions.

The BWT system also required several structural modifications to install it into the new machinery spaces. The following structural additions are required for installation of the new BWT system.

1. Add grating for one primary level across the entire new machinery space.
2. Add grating for a small secondary level around the filter unit to provide access for maintenance.
3. Install a watertight door to the new machinery space from the main engine room.
4. Refurbish and possibly relocate the existing access ladder as an emergency escape from the machinery space.
5. Replace the main deck manhole to the new machinery space with an emergency escape hatch that can be opened from inside the machinery space.
6. Provide foundations for BWT system components. This includes filters, UV reactors, back-flush pump, and all electrical power panels.
7. Provide foundations for new piping in the BWT system. This includes large headers, 30" diameter piping, and numerous smaller pipes.
8. Install new watertight bulkhead penetrations in aft bulkhead and forward bulkhead of the new machinery space.
9. Install new overboard discharge port forward in the number six ballast tanks (one discharge on starboard side and one on port side). The BWT system uses this discharge for back flush.

4.2.2.4 Vessel Two BWT System 1: Mechanical Modifications

Converting the number seven ballast tanks over to machinery spaces requires several new mechanical systems in the space. The BWT system piping and ballast modification are shown in Appendix B, Figure B-2. Each new machinery space requires the following new systems added and installation may require ship drydocking and extensive shipyard work.

1. New compartment ventilation systems. This includes a bulkhead penetration which can be made watertight to prevent progressive flooding. It also requires a fire damper because the ventilation ducting goes from the new machinery space aft into the engine room.
2. New bilge suction systems. This includes bilge piping. The new piping leads aft to the engine room and attaches to the existing bilge system manifold.
3. Based on current regulations, the current arrangement should only require fire extinguishers (Code of Federal Regulations - 46 CFR 95.50, 2011; Code of Federal Regulations - 46 CFR 95.05-10, 2011).
4. Install electric space heaters.

The installation of the BWT requires the following work to be done.

1. Install BWT filter assembly.
2. Install four BWT UV reactors.
3. Install back-flush pump for BWT system.
4. Supply pressurized air to BWT system for pneumatic control valves. Valves are actuated by BWT control system and powered by ship's supply air.
5. Remove main ballast header (existing) in main engine space and relocate slightly outboard to align with the new BWT filter unit.

6. Remove the main ballast header (existing) in new machinery space.
7. Remove part of the main ballast header (existing) in number six ballast tank to allow new piping configuration.
8. Install new 30" header pipes for main ballast system pipe.
9. Install new 10" pipes to connect the ballast stripping system into the BWT system.
10. Install new 16" drainage pipe from the BWT system forward to the new discharge port in the number six ballast tanks. Discharge port includes a gate valve with a remote operator and check valve.
11. Install new large headers and miscellaneous piping to connect the various components of the BWT system.
12. Install storage cabinets to hold spare parts and tools for maintenance of BWT system.
13. Relocate stripping system piping as necessary.
14. Modify existing piping to high suction sea chest to accept drain line from BWT system.

The new mechanical systems may interfere with existing systems and ship's structure. The installation anticipates that some amount of minor relocation is necessary.

The new electrical requirements require installation of supplemental generators in the deckhouse. Support of these generators requires installation of several new mechanical systems.

1. Install one new enclosure on each side of the vessel for supplemental generators (two new enclosures total). Ensure enclosure has suitable structural fire protection. The forward transverse bulkhead divides the new generator enclosure and the ship's galley.
2. Install one new BWT supplemental generator on each side of the vessel (two generators total). The generator is located inside the new enclosure. The capacity of each generator is 300 kW (600 kW total). An example of a suitable generator could be the Caterpillar 3406C diesel standby generator.
3. Install fuel transfer lines and valves from the existing diesel generator fuel system to the two new supplemental generators.
4. Install self-contained carbon dioxide (CO_2) fire suppression systems for each of the new supplemental generators (two new systems total).
5. Install day tanks for each new supplemental generator (two new day tanks total). Day tanks are located in the enclosure along with the generator. Tanks must have A60-rated structural fire protection.

4.2.2.5 Vessel Two BWT System 1: Electrical Modifications

An electrical load analysis addresses added power requirements from the BWT system and ship's services in the new machinery space (Appendix B, Table B-1). The total required power for all systems onboard the vessel, including the BWT modifications, is 1,791.1 kW. The two auxiliary generators installed on the ship supply 1,200 kW. Even with the existing generators, the new modifications require an additional 591 kW of power. Two new supplemental generators, installed on the 02 deck level in the superstructure, supply this power, each generator rated at 300 kW. All four generators operate in parallel.

The number seven ballast tanks require the following electrical systems installed in each tank to convert them over to machinery spaces. The new BWT systems draw power from the supplemental generators, but the existing ship's service generators supply power to the new electrical systems for the BWT machinery space (not the BWT systems themselves).

1. Install overhead lighting systems. This includes normal mains lighting and emergency lighting.
2. Install watertight bulkhead penetrations for lighting cables.
3. Install wiring and receptacle for general ship service power. Receptacles are 120 volts (V), single-phase, 60-Hertz (Hz), 13 amps (A).

There are also several other supporting installations required. The following electrical additions are necessary.

1. Install four vendor-supplied power panels for UV reactors. Power supply to panels must be 440 V, 3-phase, 60-Hz.
2. Install one vendor-supplied power panel for back-flush pump. Power supply to panel must be 440 V, 3-phase, 60-Hz.
3. Install one vendor-supplied system control panel. Power supply to panel must be 240 V, single-phase, 60-Hz.
4. Install a power switchboard for each BWT supplemental generator. Switchboard is located in the same enclosure with the supplemental generator (two switchboards total).
5. Install cross-connection between each BWT supplemental generator and between existing ship service generators. Cross-connection must include wiring for 440 V, 3-phase, 60-Hz, 7.50 A per phase. Include necessary equipment to run parallel between supplemental generators and ship service generators.
6. Install wiring for serial communication between BWT system and ship ballast management system.

4.2.2.6 Vessel Two BWT System 1: Control System Integration

Section 4.1.2.6.1 provides an overview of the two different control systems that are being considered. Each BWT system will have its own telemetry cabling to the ship's monitoring and control system. The controls for this vessel could be either hard-wire or serial. The possible cable runs would be relatively short to the engine room. The selection of a control system would be based on the ease of integration to the existing ship's monitoring/control system.

4.2.2.7 Vessel Two BWT System 1: Operational Impacts

Extra weight from the ballast system requires reduction in total cargo capacity. (See Appendix B, Table B-2 through Table B-7 for design calculations.) Total lost capacity is 167 lt (170 mt) (0.2 percent of total cargo capacity).

4.2.2.8 Vessel Two BWT System 1: Estimated Costs and Schedule Impact

The estimate for the installation of the filtration and UV reactor-type BWT system in the large capacity 1000' Laker has been done using the U. S. Navy Ship Work Breakdown System (SWBS). Because the estimate is for the modification of an existing vessel, Sections 100 (Hull Structure) through 600 (Outfitting) are formatted with removals being estimated and followed by the estimate for installations and modifications. Labor hours are estimated using data gathered from shipyard cost returns for work of this type. Current cost data and budget quotes from vendors and subcontractors are based on material costs. The estimate is based on the assumption that the work would be done during the annual winter layup. While the ship is in drydock, BWT system installation work for the hull underbody would be scheduled.

The engineering, on which the estimate is based, is at a concept design level; labor, material, and subcontractor margins of 12 percent have been used in the SWBS sections. The total cost contains an 18 percent contingency. The margins and contingencies are based on data from Naval Sea Systems

Command (August 2011). The total estimated cost for installation of a filtration and UV reactor-type BWT system in the large capacity 1000’ Laker is $11,618,542 (see Appendix B, Table B-8) and will take 15 weeks with an average manning level of 40 people.

4.2.3 Vessel Two BWT System 2: Ozone

4.2.3.1 Vessel Two BWT System 2: General

The second BWT system for Vessel One is an ozone injection system. Section 3.4.2 contains a basic description of the operation of the system. The ozone system is located in Ballast Tank 7, starboard. There are two ozone injectors, one port and one starboard(Appendix B, Figure B-3). The injectors treat the ballast water on its side of the vessel. The system is comprised of the following components:

1. Two air compressors.
2. Two coalescing filters.
3. Two air receiver tanks.
4. Two oxygen generators.
5. Two 0.01 micron filters.
6. Two oxygen receiver tanks.
7. One ozone generator.
8. One power panel for the ozone generator.
9. One high voltage transformer for the ozone generator.
10. One ozone monitor.
11. One ozone destruct column.
12. One ozone destructor.
13. Two chiller units.
14. Two condenser water pumps for the chiller units.
15. Two ozone injector fittings for the main ballast lines.
16. Two injector pumps for the side-stream ballast water.
17. Pneumatic and hydraulic piping to connect all system components.

4.2.3.2 Vessel Two BWT System 2: BWT System Arrangement

Ideally, the BWT installs in an existing machinery space. A combination of operational and practical limitations prevent this. The main engine room has little space to accommodate the numerous system components for the ozone system. The main deck of the ship is not suitable because it would interfere with ship operations. One option considered was to install a new enclosure on the deckhouse and install the ozone generation system there. The space requirements meant a very large deck enclosure, which wrapped around the deckhouse and blocked portholes to crew staterooms. The most convenient option was to convert the starboard number seven ballast tank to a new machinery space. This similar design was used for System 1 (Filter/UV) on this vessel. Only the starboard tank is converted. The port number seven tank remains operational. There will be a slight list depending on the vessel operation, which is not expected to affect operations. Initial structural analysis indication little change in the stresses in the hull. More detail analysis will have to be done during the design process.

A single system treats all ballast water. For system arrangement drawings; see Appendix B, Figure B-1. This system supplies ozone to two side-stream ballast water injection fittings. The ozone injection equipment installs in the port and starboard main ballast headers. The two sets of injection equipment can operate independently and simultaneously supporting the ozone generator.

The ozone generation system requires several supporting interfaces. The ozone system requires water circulated for cooling purposes. A new sea chest and discharge, installed in the number seven starboard ballast tank, supply the cooling water. The air compressors require a constant supply of outside air. Fans supply the air and provide adequate ventilation to the compartment. The ventilation needs to remove any hazardous vapors that could potentially accumulate from the ozone generation. The ozone generation process also creates several by-products. The system removes nitrogen from atmospheric air to generate oxygen. The waste nitrogen from this process routes to an exhaust duct. The exhaust duct also vents any excess ozone created by the ozone generator. This exhaust duct vents up to the main deck.

4.2.3.3 Vessel Two BWT System 2: Structural Changes

See Section 4.2.2.3 for the general structural changes necessary to convert the number seven starboard ballast tank over to a BWT machinery space. In addition to those general requirements, one must also install new watertight deck penetrations for ventilation ducting to the new BWT space.

The BWT machinery room includes a new mezzanine deck on which to install ozone generation equipment. The deck supports the air compressors, oxygen generators, and associated filters. This mezzanine deck is approximately 8' 11" (2.72 m) above the existing tank top. It extends from the high sea chest at frame 109 forward to the forward bulkhead. The general dimensions are 31' (9.4 m) long x 42' 6" (13.0 m) wide.

Longitudinal stiffeners are spaced every 24" to support the deck plating. Transverse web girders are normally spaced every 96" for major support structure. Vertical stanchions support these transverse girders. The transverse girders and vertical stanchions are positioned to align with existing transverse ship structure.

Because this is a concept design, structural scantlings are not calculated. The transverse girders use scantlings equivalent to the existing hull structure. Reasonable scantlings are assumed for regular longitudinal stiffeners based on designer experience. This approach ensures a conservative concept design. The following structural additions are required for the new mezzanine deck.

1. Add 11 new support pillars. Assumed scantlings are 4" x 3" x 1/4" angle. Total length is 98' (29.9 m).
2. Add 93 new support stiffeners. Assumed scantlings are 7" x 3" x 1/4" angle. Total length is roughly 1993' (607.5 m).
3. Add four new transverse girders. Assumed scantlings are 8" x 4" x 5/16" angle. Total length is approximately 167' (50.9 m).
4. Add deck plating. Assumed scantling is 1/4" plain carbon steel. Total area is approximately 1365 square feet (ft^2) (126.8 m^2).
5. Add new support brackets where stiffeners attach to existing ship bulkheads in 25 places. Assumed bracket scantlings are 12" x 1" x 1/4" triangular plate. Total area is approximately 12.5 ft^2 (1.16 m^2).
6. Add new access stairwell from tank top to new mezzanine deck. Include safety railing. Stairwell diagonal length is 12' (3.68 m).
7. Add safety railing on aft side of mezzanine deck only. All other sides border existing bulkheads.
8. Provide protective painting for all new structure.

Ventilation for the new machinery requirement requires construction of a new deckhouse enclosure on the starboard side. This is a small enclosure housing the intake louvers and exhaust louvers for the new compartment ventilation. The enclosure also houses the ventilation fans. Enclosure measures 25' (7.62 m) long x 8' (2.4 m) wide x 10' (3.0 m) high. The following structural additions are necessary.

1. Add 1/4” plate. Total plate area is approximately 860 ft^2 (79.9 m^2).
2. Add 12 transverse girders. Assumed scantlings are 4” x 3” x 1/4” angle. Total length is approximately 100’ (30.5 m).
3. Add 16 longitudinal stiffeners. Assumed scantlings are 3.75” x 1/2” flatbar. Total length is approximately 240’ (73.2 m).
4. Add new weather-tight door.
5. Provide protective painting for all new structure.

The new BWT system requires the following structural additions.

1. Provide foundations for BWT system components. This includes: air compressors; air filters; air receivers; oxygen generators; ozone generator; chiller units; seawater circulation pumps; ozone injector pumps; ozone power panels; and ozone power transformer panel.
2. Provide foundations for new pneumatic piping in the BWT system. Predominant piping diameters are 3” and 5”.
3. Provide foundations for new water piping in the BWT system. Predominant piping diameters are 6” and 12”.
4. Install new watertight bulkhead penetrations in aft bulkhead and forward bulkhead of the new machinery space.
5. Install new sea chest for 5” pipe in the double bottom of the starboard number seven ballast tank.
6. Install new watertight discharge port in the double bottom of starboard number seven ballast tank.
7. Provide foundations for new supplemental generator.

4.2.3.4 Vessel Two BWT System 2: Mechanical Modifications

Converting the number seven starboard ballast tank to a machinery space requires several new mechanical systems in the space. The BWT system piping and ballast modification are shown in Appendix B, Figure B-4. The new machinery space requires the following new systems added and installation may require ship drydocking and extensive shipyard work.

1. New bilge suction systems. This includes bilge piping. The new piping leads aft to the engine room and attaches to the existing bilge system manifold.
2. New fixed fire protection systems. The BWT machinery may require a CO2 fire suppression system. Because the new machinery space is smaller than the engine room, the existing CO2 system for the engine room can probably be modified with a branch line extending into the new machinery space and a separate pull box for the new BWT machinery space (American Bureau of Shipping, April 2011; Code of Federal Regulations - 46 CFR 95.05-10, 2011).
3. Install two new fire extinguishers. These are in addition to the fixed fire protection equipment already listed. Extinguishers should be foam spray type (American Bureau of Shipping, April 2011; Code of Federal Regulations - 46 CFR 95.50, 2011).
4. Install electric space heaters.
5. Install three new ventilation fans to supply air from main deck. Fans are rated at 14.8 horsepower (hp) (11.0 kW) each. (See Appendix B, Table B-9 for calculations.)

The ozone system is supplied as several separate components. Each component has to be installed along with the supporting ship’s systems. The following list is the hardware and system installed or modified:

1. Install two air compressors with refrigerated air dryers. Each air compressor delivers 928 standard cubic feet per minute (scfm) of air at 125 pounds per square inch (psi).

2. Install two air receiver tanks. Each tank must have a capacity of 1,600 gal (6.05 m^3).
3. Install two oxygen generators. Each generator must delivery 67 scfm of 99.5 percent oxygen by volume at a pressure of 45 psi.
4. Install two oxygen receiver tanks. Each tank must have a capacity of 1,600 gal (6.05 m^3).
5. Install one ozone generator.
6. Install two chiller units. Each chiller unit has a capacity of 630,000 British Thermal Unit (BTU)/hr.
7. Install two condenser water pumps for the chiller units. Each water pump has a capacity of 80 gpm at 75' of head.
8. Install two ozone injector fittings for the main ballast lines. Fittings must match 30" diameter of main ballast line.
9. Install two injector pumps for the side-stream ballast water line. Each pump has a capacity of 1,200 gpm at 100' of head.
10. Install pneumatic piping and fittings to connect all equipment used for ozone generation.
11. Install piping and fittings to connect all cooling equipment for ozone generation.
12. Install piping to side-stream injection line to inject ozone into main ballast water header.

The new mechanical systems may interfere with existing systems and ship's structure. The installation anticipates that some amount of minor relocation may be necessary.

The new electrical requirements require installation of a supplemental generator. The generator installs in the new machinery space with the new BWT machinery. The following items are necessary to install the new supplemental generator.

1. Install one new BWT supplemental generator in the BWT machinery space. Generator capacity is 275 kW of power. An example of a suitable generator could be the Caterpillar C9275 diesel prime generator.
2. Install fuel supply lines and valves from the main fuel system to the new supplemental generator. Generator draws fuel directly from the starboard day tank.
13. Install new exhaust duct leading from BWT machinery space to main exhaust stack and up to top of exhaust stack.

4.2.3.5 Vessel Two BWT System 2: Electrical Modifications

An electrical loads analysis considers added power requirements from the BWT system and ship's services in the new machinery space (Appendix B, Table B-10). The total required power for all systems onboard the vessel, including the BWT modifications, is 1477 kW. The two existing auxiliary generators installed on the ship supply 1200 kW. An additional 277 kW of power is required for BWT. A new supplemental generator, installed in the new BWT machinery space, supplies this power. The generator capacity is 300 kW. All three generators operate in parallel (two existing ship's generators and one new generator for the BWT system).

See Section 4.2.2.5 for general electrical changes required to convert the number seven starboard ballast tank into a new BWT machinery space.

There are also several other supporting installations required. The following electrical additions are necessary.

1. Install power panel for the ozone generator.
2. Install high-voltage transformer for the ozone generator.

3. Install cross-connection between the BWT supplemental generator and existing ship's service generators. Cross-connection must include wiring for 480 V, 3-phase, 60-Hz, 414 A per phase. Include necessary equipment to run parallel between supplemental generator and ship's service generators.
4. Install wiring for control system communication between BWT system and ship ballast management system.

4.2.3.6 Vessel Two BWT System 2: Control System Integration

Section 4.1.2.6.1 provides an overview of the two different control systems that are being considered. The BWT system will have its own telemetry cabling to the ship's monitoring and control system. The controls for this vessel could be either hard-wire or serial. The possible cable runs would be relatively short to the engine room. The selection of a control system would be based on the ease of integration to the existing ship's monitoring/control system.

4.2.3.7 Vessel Two BWT System 2: Operational Impacts

Based on weight estimates of BWT System 1 the impact on deadweight and cargo capacity should be negligible. The BWT system requires the conversion of only one ballast tank, implying less equipment and weight change. This change should have little affect on the stability of the vessel. The fully ballasted vessel has a draft of 26' and the allowable is 34'. The vessel will have a slight list to port when fully ballasted. Ballast tanks eight can be used to control the trim and list. The total change in cargo capacity is assumed less than 1 percent from changes due to addition of the new BWT system.

4.2.3.8 Vessel Two BWT System 2: Estimated Costs and Schedule Impact

The engineering, on which the estimate is based, is at a concept design level; labor, material, and subcontractor margins of 12 percent have been used in the SWBS sections. The total cost contains an 18 percent contingency. The margins and contingencies are based on data from Naval Sea Systems Command (August 2011). The total estimated cost for installation of an ozone-type BWT system in the large capacity 1000' Laker is $6,291,681 and will take 15 weeks with an average manning level of 40 people. (See Appendix B, Table B-11, for details.)

4.2.3.9 Vessel Three: Older, Small Capacity 700' – 800' Laker

Vessel Three is described as an older, small River Class vessel. It is a Great Lakes bulk carrier built in 1952 and lengthened in 1976. The vessel has been operating on the Great Lakes for 35 years. Drawings of the vessel are in Volume 1, Appendix C. The principal characteristics are shown in Table 6.

Table 6. Older, small capacity 700' - 800' Laker: principal characteristics.

Length at Waterline	742.0' after 102.0' lengthening
Beam Molded	72.0'
Draft	27.0'
Depth, Molded, Main Deck	36.0'
Camber of Main Deck, Straight Line	1.5' in ½ beam
Lightship	9,150 lt
Gross Tonnage	15,179
Net Tonnage (Registered)	11,330
Number of Cargo Holds	14
Cargo Type	Iron Ore Pellets, Coal, Limestone
Deadweight Tonnage	25,601 lt (26,011 mt)
Number of Ballast Tanks	18
Ballast Tank Capacity	62, 150 mt
Power Plant	7,700 hp (Steam)
Year Built	1952/1976 lengthened
Shipyard	Manitowoc Shipbuilding, Inc./Fraser Shipyard

The vessel arrangement has a deckhouse forward and aft; accommodations are located forward, engineer accommodations and propulsion are located aft. A self-unloading inclined belt system fits at the forward end of the cargo block, with a top side "A" frame through the spar deck, where the cargo then transfers to the cargo boom conveyor. Forward, the pilothouse is located over the accommodation deckhouse.

The cargo block divides into seven cargo holds, which vary in length; total cargo hold length is 555.0 feet. The cargo holds are comprised of 35-degree transverse slopes feeding gravity-type cargo gates, where the cargo flows onto a conveyor belt, one port and one starboard. The spar deck has hatches with covers that a hatch cover crane removes and stacks. The vessel loads at a timely rate of some 5,600 lt/hour (5,690 mt/hr.).

The installed ballast system is capable of counter-acting the loading rate of the shore facility to keep the vessel in close vertical tolerance to the loading facility. The ballast system comprises one large electric motor driven pump on each side of the vessel (two total), with a combined capacity of 21,000 gpm (4,770 m^3/hr) (10,500 gpm/2,385 m^3/hr each). The ballast system on this vessel is augmented by one smaller electric motor driven pump on each side of the vessel (two total), with a combined capacity of 4,000 gpm (908 m^3/hr) (2,000 gpm/454.2 m^3/hr each).
The ballast system on this vessel is a manifold and single line per tank type, with the single lines leading down each side of the vessel in the ballast tanks in a raft of pipes. Each manifold serves nine separate ballast tanks. Each ballast tank one through eight is fitted with a suction box, which is located close to the vessel bottom for optimum performance.

The following analyses assumed that the full pump capacity fills all the ballast tanks simultaneously. Therefore, the maximum flow rate for any one ballast tank was 1,389 gpm (315.5 m^3/hr).

4.2.4 Vessel Three, BWT System 1: Filtration and UV

4.2.4.1 Vessel Three, BWT System 1: General

The BWT System 1 considered for Vessel Three is a filtration and UV treatment system. Section 3.4.1 contains a description of the filtration and UV system. One complete BWT system is installed in the supply

line for each ballast tank. This results in 19 independent BWT systems. The systems for ballast tanks one through eight and the forepeak tank are located in the central tunnel, between the conveyor belts; see Appendix C, Figure C-1. The two number nine ballast tanks are reduced in size, and the BWT systems are installed under these modified ballast tanks.

Each complete BWT system has the following components.

1. One filtration assembly.
2. One UV reactor.
3. One back-flush pump.
4. One power supply cabinet for the UV reactor.
5. One power supply cabinet for the back-flush pump.
6. One control panel to operate the whole system.

4.2.4.2 Vessel Three, BWT System 1: BWT System Arrangement

Each BWT system is relatively small. The filters and UV reactor are skid-mounted together and installed as a single assembly. The skid assembly measures 130” (330 cm) long x 43” (109 cm) wide x 61” (155 cm) high. This does not include connecting piping. The UV power panel is installed separately from the skid assembly. This is a full height power panel measuring 47” (119 cm) wide x 16” (41 cm) deep x 75” (191 cm) tall. The power panel can be installed anywhere; it does not need to be next to the skid assembly. The control panel for each BWT system should be installed next to the skid assembly, but this is a small panel. The control panel measures only 24” (61 cm) wide x 8” (20 cm) deep x 30” (76 cm) tall.

The existing piping arrangement has a suction box for each tank located at the aft end of the tank, near centerline. This suction box is removed, and a new piping connection installed. The new connection leads up, out of the double-bottom ballast tank. The pipe connects to the BWT system (the skid assembly). The pipe then leaves the outlet of the BWT system and immediately turns down to re-enter the double bottom of the ballast tank. A new suction box is installed at this location. This arrangement moves all suction boxes forward by approximately 15’ (4.57 m).

The number nine ballast tanks require a slightly different installation. These tanks are located in the main engine room and are used to control trim and list. The existing engine room was crowded, with no large clear spaces to install the skid assembly. Instead, the bottom aft corner of each ballast tank is cut out to make space for the BWT system (one tank starboard, one tank port). New bulkheads are installed, reducing the size of these tanks approximately 7%. The existing suction is removed and the BWT system installed. New piping routes from the outlet of the BWT system forward into a suction box at the bottom corner of the ballast tank (the new bottom corner, formed from the cutout for the BWT system). This arrangement involved minimal additional piping.

4.2.4.3 Vessel Three, BWT System 1: Structural Changes

The following structural removals and modifications are required for installation of the new BWT systems.

1. Remove existing ballast system suction boxes in each ballast tank.
2. Remove plating and stiffeners in bottom aft corner of number nine ballast tanks.
3. Remove and relocate any minor interferences.

The following structural additions are required for installation of the new BWT system.

1. Add new suction boxes for ballast tanks.
2. Add new transverse watertight bulkhead for number nine tanks (plating and stiffeners).
3. In the number nine trim tanks, add new horizontal deck for partial tank bottom (plating and stiffeners).
4. Add foundations for skid mount of all 19 BWT systems
5. Add foundations for power panels of all 19 BWT systems.
6. Add two new discharge ports on the bottom of the vessel hull, near frame 150.
7. Provide foundations for new piping in BWT system. This includes piping leading into each BWT system and the two drain pipes, which run nearly the entire length of the vessel.
8. Install two new watertight tank penetrations for each BWT system (38 penetrations total).

4.2.4.4 Vessel Three, BWT System 1: Mechanical Modifications

The necessary modifications to install each BWT system were simple; they almost exclusively involve piping; see Appendix C, Figure C-2. The significant effort came from the quantity of BWT systems (19 total). The following mechanical components were removed or modified for each BWT system installation.

1. Remove piping leading to suction box in each tank for ballast tanks one through eight and the forepeak tank.
2. Remove piping in engine room that leads from the ballast manifold to the number nine ballast tanks.

Each BWT system required installation of the following new mechanical components.

1. Install BWT skid assembly (19 skids total). Each skid includes filter assembly and UV reactor.
2. Install back-flush pump for each BWT system (19 pumps total).
3. Install BWT power panel for UV reactor (19 panels total). For convenience, each panel is located in the same area as the BWT system it serves.
4. Install BWT system control panel (19 panels total). For convenience, each panel is located the same area as the BWT system it serves.
5. Supply pressurized air to each BWT system for pneumatic control valves. Valves are actuated by BWT control system and powered by ship's supply air.
6. New 10" connection pipes for each BWT system (19 systems total).
7. New 5" drain pipe for BWT systems. (Two pipes total, running nearly the entire length of the vessel.) Includes check valve and gate valve at the new discharge port.
8. New 5" connection pipes to connect each BWT system to the drain pipe. Includes check valves for each connection branch. (Seventeen short pipes for ballast tanks one through eight and the forepeak tank, two long pipes for the number nine ballast tanks.)
9. Storage cabinets to hold spare parts and tools for maintenance of BWT system.

All new piping systems use Victaulic slip-on type couplings. This greatly minimizes welding for the new piping system and virtually eliminates installation rework. The vessel's ballast system already uses these couplings; they should be easily compatible with the existing piping.
An additional generator is necessary to supplement the existing electrical system to be able to power all of the ballast pumps and BWT systems at once. The installation requires space and machinery reconfiguration on the main deck. The following are the preliminary and estimated structural additions required to support installation of the new generator.

1. Reconfigure a location on the main deck level to fit a new generator, including relocation of miscellaneous machinery and shop spaces (frame 202-208 port side).

2. Install new deck stiffeners, supports and foundations for the new generator.
3. Install one new BWT supplemental generator on the main deck, port side of the vessel. The generator supplies 550 ekW of power. An example of a suitable generator is the Caterpillar C18 generator.
4. Install fuel transfer lines and valves from the existing auxiliary fuel system to the new supplemental generator.
5. Install self-contained CO2 fire suppression system for the new supplemental generator.
6. Install fuel tank for new supplemental generator with the capacity to allow at least 24 hours of continuous generator operation, under full power load conditions). Day tank shall be within the generator space. Tanks must have A60-rated structural fire protection.

Each of these new mechanical systems may interfere with existing systems and ship's structure. The installation anticipates some amount of minor relocation may be necessary. Installation of the skid assemblies for ballast tanks one through eight and the forepeak tank likely requires removal of the cargo hold plating for access to the center tunnel. Installation in the number nine ballast tanks could require removal of bottom hull plating for access. Installation may require ship drydocking and extensive shipyard work.

4.2.4.5 Vessel Three, BWT System 1: Electrical Modifications

An electrical loads analysis considered added power requirements from the BWT system and ship's services installed in the new machinery space. The total required power for all systems onboard the vessel, including the BWT modifications, is 1585 kW; see Appendix C, Table C-1. The two existing auxiliary generators supply 1,200 kW. Supplemental power is required. This supplemental power comes from a new auxiliary generator.

The electrical loads analysis showed that the full demand of 1585 kW was only required during loading and unloading operations, assuming that no propulsion gear was operating, i.e that the vessel did not require its thrusters to maintain station if the vessel is not alongside a "hard" bulkhead. When at sea, the existing generators meet the demand of normal ship service, total load of 855 kW. When loading and unloading, the ship uses 650 kW for ship services (Appendix C, Table C-1). To meet the total required for BWT systems and back-flush pumps of 930 kW (full demand of 1585 kW), the vessel has a new supplemental generator, rated at 550 ekW. During ballasting operations, all of the generators operate in parallel.

The following electrical additions are installed or modified.

1. Install 19 vendor-supplied power panels for UV reactors. Power supply to panels must be 440 V, 3-phase, 60 Hz.
2. Install 19 vendor-supplied system control panels. Power supply to panels must be 240 V, single-phase, 60 Hz.
3. Install new switchboard to distribute power to the UV reactor power panels of all 19 BWT systems. Supplied power will be 440 V, 3-phase, 60 Hz.
4. Install wiring to distribute power from BWT switchboard to each UV reactor power panel. Wiring must supply 440 V, 3-phase, 60 Hz power.
5. Install second switchboard to distribute power to the control panels of all 19 BWT systems. Supplied power will be 240 V, single-phase, 60 Hz.
6. Install wiring for serial communication between BWT system and ship ballast management system (19 Ethernet cables, all routing to central control circuits for ship ballast management system).

4.2.4.6 Vessel Three, BWT System 1: Control System Integration

Section 4.1.2.6.1 provides an overview of the two different control systems that are being considered. The BWT system for Vessel One has 19 individual systems. A monitoring/control signal from each system needs to be integrated into the ship's control system. Serial communication reduces the number of telemetry cables required to safely integrate the BWT monitoring/control system. The ozone equipment is located in various locations on the ship. One telemetry cable provides the flexibility to integrate the BWT system with the ship's monitoring/control system. The hard-wire system would be routed through different areas of the spaces that have BWT equipment. This adds to the number of cables and the complexity of installation. The serial control system is recommended.

4.2.4.7 Vessel Three, BWT System 1: Operational Impacts

The added weight from the ballast system reduces the cargo capacity. (See Appendix C, Table C-2.) Total lost capacity is 51.1 lt (52.0 mt), a 0.15 percent reduction of total cargo capacity.

4.2.4.8 Vessel Three, BWT System 1: Estimated Costs and Schedule Impact

The engineering, on which the estimate is based, is at a concept design level; labor, material, and subcontractor margins of 12 percent have been used in the SWBS sections. The total cost contains an 18 percent contingency. The margins and contingencies are based on data from Naval Sea Systems Command (August 2011). The total estimated cost for installation of filtration + UV type BWT system in Vessel Three is $8,780,039 and will take 23 weeks with an average manning level of 30 people; see Appendix C, Table C-3).

4.2.5 Vessel Three, BWT System 2: Ozone

4.2.5.1 Vessel Three, BWT System 2: General

The second BWT system considered for Vessel One is an ozone injection system. Section 3.4.2 contains a basic description of the operation of the system. The ozone system is distributed over several decks. The ozone is injected into the main ballast pipe line.

A single BWT system is installed in Vessel Three. The ozone treatment system on Vessel Three consists of the following major components.

1. One air compressor.
2. One coalescing filter.
3. One air receiver tank.
4. One oxygen generator.
5. One 0.01 micron filter.
6. One oxygen receiver tank.
7. One ozone generator.
8. One power panel for the ozone generator.
9. One high voltage transformer for the ozone generator.
10. One ozone monitor.
11. One ozone destruct column.
12. One ozone destructor.
13. One chiller unit.
14. One condenser water pumps for the chiller unit.
15. Two ozone injector fittings for the main ballast lines.
16. Two injector pumps for the side-stream ballast water.
17. Pneumatic and hydraulic piping to connect all system components.

4.2.5.2 Vessel Three, BWT System 2: BWT System Arrangement

A single system treats all ballast water. For system arrangement drawings, see Appendix C, Figure C-3. The system is distributed across several decks, with the majority of the components in the decommissioned coal bunker on the port side spar deck. This system supplies ozone to two side-stream ballast water injection fittings. The ozone injection equipment installs in the port and starboard main ballast lines, between the sea chest and main ballast pumps. The two sets of injection equipment operate independently.

The ozone generation system requires seawater circulation for cooling purposes. Lines are added to the existing sea chest and overboard on the starboard side. These new lines supply cooling water. The air compressor requires a constant supply of atmospheric air. Because the air compressor is located within the main engine room, the existing fans are assumed to supply enough air. Additional ventilation is provided for the new ozone room on the spar deck. This ventilation removes any hazardous vapors that could accumulate from the ozone generation. The ozone generation process also creates several by-products. The system removes nitrogen from atmospheric air to generate oxygen. The waste nitrogen from this process routes to an exhaust duct. The exhaust duct also vents any excess ozone created by the ozone generator. This exhaust duct vents out the side shell of the ship to the atmosphere.

Ideally, the BWT would be installed in an existing machinery space. A combination of operational and practical limitations, however, prevents this. The main engine room has little space to accommodate all of the BWT system components. The main deck of the ship is not suitable because it interferes with ship operations.

The most convenient option is to distribute the equipment into several locations. The oxygen generator, ozone generator, and any other equipment that could generate harmful vapors are installed in the new ozone space. The remaining equipment is distributed around the main engine room.

4.2.5.3 Vessel Three, BWT System 2: Structural Changes

The ozone machinery is dispersed across several decks. The largest concentration of machinery is on the spar deck, from frame 193 to frame 200, on the port side only. This area was originally the engineer’s store room and a decommissioned coal bunker. The space is converted over to a new machinery space named the ozone room. The conversion requires the following structural changes.

1. Remove longitudinal bulkhead (plating and stiffeners) at 23’ (7.01 m) to port of centerline.
2. Add header beam and other necessary structural reinforcements to compensate for bulkhead removal.
3. The plating in the coal bunker is assumed to have significant damage and wear. Inspect and renew plating as appropriate.

The creation of the new machinery space on the spar deck eliminates the engineer’s storeroom. Create a new storage space for compensation. The new storage space is created on the spar deck, on starboard side, from frame 193 to frame 200. This was the starboard-decommissioned coal bunker. The conversion to a storage space requires the following structural changes.

1. Install new joiner access door at frame 193 to access the new storage space.
2. The new engineer’s storeroom has a smaller floor plan than the previous one. To compensate, the full, two- deck height of the new store room is used. New storage shelves extend the entire height of the coal bunker, with personnel access to a second level. Inside the coal bunker, provide a vertical access ladder and catwalk to reach the upper deck of the storage room.
3. Install structural shelving capable of supporting the weight of numerous engine spares and supplies.

The new BWT system requires the following structural additions.

1. On the spar deck, provide foundations for BWT system components. This includes ozone generator, oxygen generator, air receiver, oxygen receiver, ozone monitor, and ozone destruct unit.
2. On the main deck, provide foundations for BWT system components. This includes air compressor, chiller unit, ozone power panel, and ozone high voltage transformer.
3. On the main deck, at frame 208, extend deck plating and stiffeners 43" (109 cm) forward to provide access to the air compressor on all sides. Include safety railings and toe rail on the extended platform.
4. Relocate miscellaneous machinery on main deck. Original location is from frame 202 to frame 208, port side. Remove from original location and reinstall on port side, from frame 208 to frame 211. Reroute any piping as necessary.
5. On the working deck, provide foundations for BWT system components. This includes injection pumps and ozone injector units.
6. On the engine room floor, provide foundations for BWT system components. This includes the condenser pump.
7. Provide foundations for new pneumatic piping in the BWT system. Predominant piping diameters are 2" and 4".
8. Provide foundations for new cooling water piping in the BWT system. Predominant piping diameter is 3".
9. Install new watertight deck penetrations in the following decks: spar deck (quantity 4); main deck (quantity 5); working deck (quantity 6).
10. Attach 3" water pipe to existing sea chest on starboard side, at frame 195. Include gate valve.
11. Attach 3" water pipe to existing overboard on starboard side, at frame 209. Include gate valve.

4.2.5.4 Vessel Three, BWT System 2: Mechanical Modifications

Conversion of the coal bunkers to a machinery space (port side) and a storage space (starboard side) requires new mechanical systems in the space; see Appendix C, Figure C-4. Add the following new systems; installation may require ship drydocking and extensive shipyard work.

1. Install new fire extinguishers: one fire extinguisher per space.
2. Install one new ventilation fan to supply air to the ozone space, with a minimum capacity of 15,800 cfm. Fan is rated at 4.10 hp (3.06 kW) each. (See Appendix C, Table C-4) Install fan in existing fan room on spar deck.
3. Install new ventilation ducting to run from existing fan room to new ozone room. Route ventilation through overhead space, if possible.
4. In the starboard engineer's storeroom, install a dumbwaiter or similar lifting appliance between the spar deck and the second deck of the new storage room.
5. Install a small ventilation fan to circulate air in the new engineer's storeroom.

The BWT system also requires several forms of machinery and supporting ship services.

1. Install one air compressor with refrigerated air dryer. Air compressor delivers 583 scfm of air at 120 psi.
2. Install one air receiver tank. Tank must have a capacity of 1,600 gal (6.05 m3).
3. Install one oxygen generator. Each generator must deliver 53 scfm of 99.5 percent oxygen by volume at a pressure of 45 psi.
4. Install one oxygen receiver tank. Tank must have a capacity of 1,600 gal (6.05 m^3).

5. Install one ozone generator.
6. Install one chiller unit. Each chiller unit has a capacity of 464,000 BTU/hr.
7. Install one condenser water pump for the chiller unit. Water pump has a capacity of 75 gpm (17 m^3/hr.) at 75' (23 m) of head.
8. Install two ozone injector fittings for the main ballast lines. Fittings must match 20" diameter of main ballast line.
9. Install two injector pumps for the side-stream ballast water line. Each pump has a capacity of 280 gpm (63.6 m^3/hr) at 300' (91.4 m) of head.
10. Install pneumatic piping and fittings to connect all equipment used for ozone generation. Predominant piping diameters are 2" and 4".
11. Install piping and fittings to connect all cooling equipment for ozone generation. Predominant piping diameter is 3".
12. Install piping for side-stream injection line to inject ozone into main ballast water header.

The new mechanical systems may interfere with existing systems and ship's structure. The installation anticipates that some amount of minor relocation may be necessary.

4.2.5.5 Vessel Three, BWT System 2: Electrical Modifications

An electrical loads analysis considers added power requirements from the BWT system and ship's services in the new machinery space. The total required power for all systems onboard the vessel, including the BWT modifications, is 1200 ekW. The two auxiliary generators installed on the ship supply are 1200 kW. No additional power is required. This analysis assumes both auxiliary generators operate in parallel.

The new ozone space and new engineer's stores on the spar deck require the following electrical systems installed to convert them over to machinery and storage spaces, respectively:

1. Install overhead lighting systems. This includes normal mains lighting and emergency lighting.
2. Install watertight bulkhead penetrations for lighting cables.
3. Install wiring and receptacles for general ship service power. Receptacles are 120 V, single-phase, 60 Hz, 15 A.

There are also several other supporting installations required. The following electrical additions are necessary.

1. Install power panel for the ozone generator on main deck.
2. Install high voltage transformer for the ozone generator on main deck.
3. Supply wiring for power connection to ozone generator: 370 kW at 480 V, three-phase.
4. Supply wiring for power connection to oxygen generator: 50 W at 120 V, single-phase.
5. Supply wiring for power connection to air compressor: 140 kW at 460 V, three-phase.
6. Supply wiring for power connection to chiller unit: 68 kW at 460 V, three-phase.
7. Supply wiring for power connection to condenser pump: 2.9 kW at 230 V, single-phase.
8. Supply wiring for power connection to each injection pump (2 total): 34.7 kW at 460 V, three-phase.
9. Install wiring for control system communication between BWT system and ship ballast management system.

4.2.5.6 Vessel Three, BWT System 2: Control System Integration

Section 4.1.2.6.1 provides an overview of the two different control systems that are being considered. Each BWT system will have its own telemetry cabling to the ship's monitoring and control system. The equipment for the BWT system is located in various places on the ship. The serial communication system provides flexibility integrating the BWT system with the ship's monitoring/control system. A single telemetry cable could be used allowing for flexible routing through the ship. The hard-wire system requires more telemetry cable to integrate the BWT equipment. The serial communication system is recommended for this application.

4.2.5.7 Vessel Three, BWT System 2: Operational Impacts

The added weight from the ballast system reduces the cargo capacity; see Appendix C, Table C-6. Total lost capacity is 57.2 lt (58.1 mt), a 0.2 percent reduction of total cargo capacity.

4.2.5.8 Vessel Three, BWT System 2: Estimated Costs and Schedule Impact

The engineering, on which the estimate is based, is at a concept design level; labor, material, and subcontractor margins of 12 percent have been used in the SWBS sections. The total cost contains an 18 percent contingency. The margins and contingencies based on data from Naval Sea Systems Command (August 2011). The total estimated cost for installation of an ozone-type BWT system in Vessel Three is $3,457,000 and will take 11 weeks with an average manning level of 30 people; see Appendix C, Table C-10.

4.3 Vessel Four: Newer, Intermediate Capacity 800' – 900' Laker

Vessel Four is an intermediate-sized, articulated tug-barge (ATB) vessel. It is a Great Lakes bulk carrier built in 2000 at Halter Marine & Great Lakes Shipyard. The vessel has been operating on the Great Lakes for 11 years. Drawings of the vessel are in Volume 1 Appendix A. Table 7 lists the principal characteristics of the vessel.

Table 7. Vessel Four particulars.

Length at Waterline	740.0' (without tugboat)
Beam Molded	78.0
Draft	27.5'
Depth, Molded, Main Deck	45.0'
Camber of Main Deck, Straight Line	--
Lightship	6235 lt
Gross Tonnage	15,823
Net Tonnage (Registered)	15.823
Number of Cargo Holds	7
Cargo Type	Iron Ore Pellets, Coal, Limestone
Deadweight Tonnage	39,600 lt (40,235 mt)
Number of Ballast Tanks	17
Ballast Tank Capacity	24,121 mt
Power Plant	--
Year Built	2000
Shipyard	Halter Marine & Great Lakes

The arrangement of the vessel features a deckhouse aft that is the main support for the unloading boom conveyor, a component of the self-unloading system, located partly in the aft end of the cargo block and partly within the machinery space below the main deck. The barge has a small lookout house forward, which also houses the anchor windlass. The aft machinery space is 40' (12.19 m) long. The cargo block has seven separate cargo holds, which vary in length from 72' to 120' (21.95 m to 36.58 m). The bottom of each cargo hold consists of 35-degree transverse slopes that feed gravity-type cargo gates, where the cargo flows onto a single conveyor belt. The main deck has 26 hatches, with covers that a crane removes and stacks prior to loading.

The installed ballast system is capable of counter-acting the loading (or unloading) rate of the shore facility, to keep the vessel at a nearly constant draft during cargo operations. The ballast system has one large hydraulically driven pump on each side of the vessel (two pumps total). Each pump has a capacity of 14,000 gpm (3,180 m^3/hr) (combined capacity of 28,000 gpm/6,360 m^3/hr). The ballast pumps are driven by a 225 hp diesel hydraulic power unit.

The ballast piping system on this vessel consists of a single header leading down each side of the vessel and located in the ballast tanks with branch lines to each tank. The main header is a 24" diameter pipe for most of the length, but tapers to a 12" diameter at the forward extreme, and the forepeak tank. Each ballast tank is fitted with a 12" diameter branch line and remotely controlled, powered valve located in the unloading tunnel, and suction box, which is located close to the vessel bottom for optimum performance. The vessel also has a stripping system comprised of 14 submersible pumps, one in each tank. Each stripping pump has a capacity of 400 gpm, (91 m^3/hr) through a 4" diameter pipe tied in to the 12" tank branch lines. The following analysis assumes that the vessel does not run the stripping pumps at the same time as the main ballast pumps; thus, the maximum ballast flow rate for the vessel is 28,000 gpm (6360 m^3/hr).

4.3.1 Vessel Four, BWT System 1: Filtration and UV

4.3.1.1 Vessel Four, BWT System 1: General

The first BWT system considered for Vessel Four is a filtration and UV treatment system. Section 3.4.1 contains a basic description of the operation of the system. The vessel requires two BWT systems, one for the port side and one for the starboard side.

For this vessel, each complete BWT system has the following components.

1. Four large filters.
2. Three UV reactors.
3. Three power supply cabinets for the UV reactors.
4. One control panel to operate the whole system.
5. One power supply panel for the back-flush pump.

Each complete BWT system operates independently, with both systems coordinated by the ship's ballast management system.

4.3.1.2 Vessel Four, BWT System 1: BWT System Arrangement

There are two BWT systems, one for the starboard ballast pump and one for the port ballast pump. Both the port and starboard systems have the same arrangement, but opposite hand; see Appendix D, Figure D-1. The two systems are independent from each other, but a crossover between ballast systems allows one BWT system to provide for all of the tanks.

To install the new BWT systems, the vessel requires a new mezzanine deck in the aft machinery space that contains the existing ballast system. The various components of the new BWT system sit on this mezzanine deck. The largest component is the filter assembly. Because of their size, the placement of the filter assembly is such that the filter pressure vessels sit on the mezzanine deck and the connecting piping is below the mezzanine deck. The filter assembly runs transversely and nearly fills the outboard half of the new mezzanine deck. The UV reactors are inboard of the filter assembly. A common header pipe connects all UV reactors in parallel to the outlet of the filter assembly. The back-flush pump sits between the UV reactors and filter assembly. The UV reactors, filter assembly, back-flush pump, and connecting piping fill almost the entire space of the mezzanine deck.

The UV reactor power panels for the BWT system are located one deck up, in the space occupied by the auxiliary generator and diesel hydraulic power unit (HPUs). The system control panel and back-flush pump panel are located within the machinery room in the available space between existing equipment.

4.3.1.3 Vessel Four, BWT System 1: Structural Changes

The following structural modifications are required for installation of each new mezzanine deck (two decks total).

1. Add longitudinal stiffeners and filter cutout headers, 18” x 4” x 1/2” angles.
2. Add transverse girders, composed of built-up T sections measuring 18.5” x 12” x 1/2”.
3. Add a longitudinal mid-span girder, composed of a built-up T section measuring 18.5” x 12” x 1/2”.
4. Add deck plating for mezzanine deck: 3/8” thick plating.
5. Add the miscellaneous brackets to attach stiffeners and girders to surrounding bulkheads.
6. Add new safety railing and stairway to access the mezzanine deck.

4.3.1.4 Vessel Four, BWT System 1: Mechanical Modifications

There are several mechanical modifications to incorporate the BWT systems into the vessel. First, the pump outlet must route upward to the filter assembly, instead of connecting to the ballast water header and sea chest return connections; see Appendix D, Figure D-2. The return lines from the BWT system must connect back into the ballast water and sea chest return lines. This includes removal of a section of piping, re-orientation of a tee connection, and relocation of two valves.

Each BWT system requires installation of the following new mechanical components.

1. Install four filters in a parallel-flow configuration.
2. Install three UV reactors.
3. Install one back-flush pump.
4. Install three BWT power panels for the UV reactors.
5. Install one BWT system control panel.
6. Install one back-flush pump panel.
7. Supply pressurized air to each BWT system for pneumatic control valves.
8. Install new 20” piping connecting the BWT system into the ballast system.
9. Install new 16” UV reactor piping, including three valves to isolate the reactors.
10. Install new 10” back-flush piping, including two valves to isolate the back-flush pump.
11. Install new 10” drain piping, including a check valve and gate valve at the new discharge port.
12. Provide storage cabinets to hold spare parts and tools for maintenance of BWT system.

Each of these new mechanical systems may interfere with existing systems and ship's structure. The installation anticipates some amount of minor relocation work. Installation of the equipment requires removal of either deck plating or hull plating for access to the machinery space. Installation will require extensive shipyard work, and may require ship drydocking. However, drydocking costs have not been factored into the cost estimates, as this work can be accomplished during a normal required drydock period, and production plans could be developed that do not require drydocking the vessel.
New supplemental generators installed in enclosures mounted on the deckhouse will meet the new electrical requirements. Several new mechanical systems are required to support the generators.

1. Install one new enclosure on each side of the vessel for supplemental BWT supply generators (two new enclosures total). Enclosures must have A60-rated structural fire protection.
2. Install one new BWT supplemental generator on each side of the vessel (two generators total). Generator is located inside the new enclosure. Each generator supplies 550 ekW of power (1,100 ekW total). An example of a suitable generator is the Caterpillar C18 generator.
3. Install fuel transfer lines and valves from the main fuel system to the two new supplemental generators.
4. Install self-contained CO2 fire suppression systems for each of the new supplemental generators (two new systems total).
5. Install fuel tanks for each new supplemental generator (two new tanks total, each with the capacity to allow at least 24 hours of continuous generator operation, under full power load conditions). Day tanks shall be within in the enclosure along with the generator. Tanks must have A60-rated structural fire protection.

4.3.1.5 Vessel Four, BWT System 1: Electrical Modifications

The vessel has one generator, capable of supplying 260 ekW, and a connection to the tug, which can supply an additional 120 ekW. The vessel uses 99 percent of the tug's available power supply (120 ekW) while at sea in winter, and 87 percent of the generator's electrical capacity during unloading. Based on this, the power for the BWT system must come entirely from new generators. The total required power for the BWT systems and back-flush pumps is 1,084 ekW; see Appendix D. To meet this requirement, the vessel has two new supplemental generators, each rated at 550 ekW. During ballasting operations, all of the generators operate in parallel.

The electrical systems require several other supporting installations. The following electrical additions are necessary.

1. Install six vendor-supplied power panels for UV reactors. Power supply to panels must be 440 V, 3-phase, 60 Hz.
2. Install two vendor-supplied system control panels. Power supply to panels must be 240 V, single-phase, 60 Hz.
3. Install two vendor-supplied power panels for the back-flush pumps. Power supply to panels must be 440 V, 3-phase, 60 Hz.
4. Install a power switchboard for each BWT supplemental generator, two switchboards total. Each switchboard is located in the same enclosure with the supplemental generator.
5. Install wiring for serial communication between the BWT systems and the ship's ballast management system.

4.3.1.6 Vessel Four, BWT System 1: Control System Integration

Section 4.1.2.6.1 provides an overview of the two different control systems that are being considered. Each BWT system will have its own telemetry cabling to the ship's monitoring and control system. The equipment for the BWT system is located in various places on the ship. The serial communication system provides flexibility integrating the BWT system with the ship's monitoring/control system. A single telemetry cable could be used allowing for flexible routing through the ship. The hard-wire system requires more telemetry cable to integrate the BWT equipment. The serial communication system is recommended for this application.

4.3.1.7 Vessel Four, BWT System 1: Operational Impacts

The additional weight from installing the BWT systems reduces total cargo capacity of the vessel; see Appendix D. Total lost capacity is 79.7 lt (81.0 mt), a 0.13 percent reduction in cargo capacity.

4.3.1.8 Vessel Four, BWT System 1: Estimated Costs and Schedule Impact

The estimate for the installation of the filtration and UV reactor-type BWT system in the Newer, Intermediate Capacity (800' – 900' without tug) Laker has been done using the U. S. Navy SWBS. Because the estimate is for the modification of an existing vessel, Sections 100 (Hull Structure) through 600 (Outfitting) are formatted with removals being estimated and followed by the estimate for installations and modifications. Labor hours are estimated using data gathered from shipyard cost returns for work of this type. Current cost data and budget quotes from vendors and subcontractors are based on material costs. The estimate is based on the assumption that the work would be done during the annual winter layup. While the ship is in drydock, BWT system installation work for the hull underbody would be scheduled.

The engineering, on which the estimate is based, is at a concept design level; labor, material, and subcontractor margins of 12 percent have been used in the SWBS sections. The total cost contains an 18 percent contingency. The margins and contingencies based on data from Naval Sea Systems Command (August 2011). The total estimated cost for installation of a filtration and UV reactor-type BWT system in this vessel is approximately $7,944,900, and will take 15 weeks with an average manning level of 30 people; see Appendix D, Table D-3.

4.3.2 Vessel Four, BWT System 2: Ozone

4.3.2.1 Vessel Four, BWT System 2: General

The second BWT system considered for Vessel One is an ozone injection system. Section 3.4.2 contains a basic description of the operation of the system. The vessel requires one complete ozone system (compressor, oxygen generator, receivers, ozone generator, and chiller). The ozone generation equipment all fits in the vessel's machinery space. The ozone generator supplies ozone for the two ozone injectors, one for each ballast header supplying the port and starboard sides of the vessel.

4.3.2.2 Vessel Four, BWT System 2: BWT System Arrangement

The components of the ozone generation system fit within the machinery space; either on the newly created mezzanine deck, or in the available space between existing equipment; see Appendix D, Figure D-3. The port machinery space houses the ozone generator, air compressor, and receivers, while the starboard machinery space has the oxygen generator, chiller, and ozone generator's power panel and transformer. There is an injector pump on each side of the vessel to supply the ballast piping on that side.

4.3.2.3 Vessel Four, BWT System 2: Structural Changes

The structural modifications required to install the ozone system are similar to those described in Section 4.3.1.3. The structure of the mezzanine decks consists of the same major components listed, but the decks are located at a lower height and each deck has an opening to fit the oxygen generator and receivers.

4.3.2.4 Vessel Four, BWT System 2: Mechanical Modifications

Adding the BWT systems to the machinery space may require several new mechanical systems in the space; see Appendix D, Figure D-4. Installing the following systems ensures safe and efficient operation of all the BWT systems.

1. Add an additional 24,000 cfm of ventilation capacity to the machinery space containing the air compressor and ozone generator; see Appendix D, Table D-4.
2. A 42" Hartzell Series 46 fan is a possible option to provide sufficient ventilation capacity.

The BWT systems also require several forms of supporting machinery and ship services.

1. Install one air compressor.
2. Install one compressed air receiver.
3. Install one oxygen generator.
4. Install one oxygen receiver.
5. Install one ozone generator and its power/control panel and high voltage transformer.
6. Install one chiller unit and condenser water pump.
7. Install new 1.5" and 2" air/oxygen supply system piping.
8. Install new 2" nitrogen vent and ozone vent/destruct piping.
9. Install new 3" chiller supply, drain, and recirculation pipes.
10. Install new 1.5" pipes to distribute ozone to the ozone injector pumps.
11. Install two ozone injector pumps.
12. Install new 4" ozone injector piping loop.
13. Install two ozonated-water injection sections into the 24" ballast piping.
14. Install storage cabinets to hold spare parts and tools for maintenance of BWT system.

Each of these new mechanical systems may interfere with existing systems and ship's structure. The installation anticipates some amount of minor relocation work. Installation of the large mechanical systems likely requires removal of the side shell plating to gain access to the machinery spaces. Installation will require extensive shipyard work, and may require ship drydocking. However, drydocking costs have not been factored into the cost estimates, as this work can be accomplished during a normal required drydock period, and production plans could be developed that do not require drydocking the vessel.

New supplemental generators installed in enclosures on the main deck will meet the new electrical requirements. Several new mechanical systems are required to support the generators.

1. Install one new enclosure for the supplemental BWT supply generator. Enclosure must have A60-rated structural fire protection.
2. Install one new BWT supplemental generator. Generator is located inside the new enclosure. Generator supplies up to 910 ekW of power. An example of a suitable generator is the Caterpillar 3508B generator.
3. Install fuel transfer lines and valves from the main fuel system to the two new supplemental generators.

4. Install a self-contained CO2 fire suppression system for the new supplemental generator.
5. Install a fuel oil day tank for the new supplemental generator. Day tanks shall be within the enclosure along with the generator. Tanks must have A60-rated structural fire protection.

4.3.2.5 Vessel Four, BWT System 2: Electrical Modifications

Section 4.1.2.5 lists the assumptions used to determine that the vessel has no extra electrical capacity with which to supply the BWT systems. Based on those assumptions and the electrical requirements of the ozone system, the total additional power requirement when all of the ozone generation equipment and injection pumps are operating is 720 ekW; see Appendix D, Table D-5. To meet this requirement, the vessel shall have a new supplemental generator, rated at 910 ekW. During ballasting operations, the BWT generators operate in parallel on their own electric bus. Independent of these BWT generators, the diesel generator and the diesel driven hydraulic power units also operate for ballasting operations.

The electrical systems require several other supporting installations. The following electrical additions are necessary.

1. Install vendor-supplied power panel and high voltage transformer for the ozone generator. Power supply to panel must be 480 V, 60 Hz, 3-phase power capable of supplying 370 kW.
2. Install two motor controllers for the ozone injection pumps. Power supply must be 460 V, 3-phase, 60 Hz.
3. Install one motor controller for the chiller water pump. Power supply must be 460 V, 3-phase, 60 Hz.
4. Install 460 V, 3-phase, 60 Hz wiring for the air compressors.
5. Install 120 V, 1-phase, 60 Hz wiring for the oxygen generators.
6. Install 460 V, 3-phase, 60 Hz wiring for the chiller units.
7. Install one power switchboard for the BWT supplemental generator. The switchboard is located in the same enclosure as the supplemental generator.
8. Install wiring between the BWT systems and the ship's ballast management system.

4.3.2.6 Vessel Four, BWT System 2: Control System Integration

The ozone generator needs to run continuously during ballasting, but not during deballasting. The ozone generator must start just before ballasting begins, and the two ozone injection pumps must run in parallel with the ballast pumps that they are servicing. In addition to the ozone generator, there are several auxiliary components that must work together seamlessly for the whole system to run properly. The compressors and oxygen generators must automatically supply the receivers, keeping them filled to a set level. The ozone generator runs the chiller units as necessary.

Ideally, the ozone system and ozone injector pumps would be completely integrated into the ship's control/monitoring system. The advantages of this is that there will be no need to have additional panels in control areas, and the entire process can be monitored in the same way the crew currently controls the ballast systems. There are two main ways to achieve the control integration. The first and most basic are hard-wiring inputs and outputs. The second and most informative technique is through serial communication. Section 4.1.2.6.1 gives a comparison of hard-wiring and serial control methods. For this vessel, with its simple, centrally located system, a hard-wired control system is an acceptable arrangement.

4.3.2.7 Vessel Four, BWT System 2: Operational Impacts

The additional weight from installing the ozone BWT system reduces the total cargo capacity of the vessel. (See D.2.3 for design calculations.) Total estimated lost capacity is approximately 57.1 lt (0.15 percent of total cargo capacity).

4.3.2.8 Vessel Four, BWT System 2: Estimated Costs and Schedule Impact

The estimate for the installation of the ozone-type BWT system in the newer, intermediate capacity (800' – 900' without tug) Laker has been done using the U. S. Navy SWBS. Because the estimate is for the modification of an existing vessel, Sections 100 (Hull Structure) through 600 (Outfitting) are formatted with removals being estimated and followed by the estimate for installations and modifications. Labor hours are estimated using data gathered from shipyard cost returns for work of this type. Current cost data and budget quotes from vendors and subcontractors are based on material costs. The estimate is based on the assumption that the work would be done during the annual winter layup. While the ship is in drydock, BWT system installation work for the hull underbody would be scheduled.

The engineering, on which the estimate is based, is at a concept design level; labor, material, and subcontractor margins of 12 percent have been used in the SWBS sections. The total cost contains an 18 percent contingency. The margins and contingencies based on data from Naval Sea Systems Command (August 2011). The total estimated cost for installation of an ozone-type BWT system in this vessel is $6,331000, and will take 12 weeks with an average manning level of 30 people; see Appendix D, Table D-7.

5 ALTERNATIVE BWM METHOD A: MUNICIPAL SEWAGE TREATMENT

5.1 Method A: General System Description

This section investigates alternative options to onboard BWT. One method is to transfer the ballast water over to storage tanks on shore and use municipal sewage treatment plants to treat the ballast water. (The second, a dedicated BWT facility at the loading dock, will be reviewed in Section 6). ***Note***: ***This is a notional concept: one major ore loading facility in one municipal area. The description does not account for a situation where there might be multiple loading facilities in a "metropolitan" Great Lakes port that might share a regional sewage treatment facility.*** The loading facility owns this transfer and storage system. This section summarizes general information and describes how this alternative would work. Discussions on estimated costs and overall practicability of this alternative are also included.

Pumping ballast water to shore requires minor modifications to the vessel, with most of the equipment located on shore. With a normal, unmodified, ship ballast system, pumps transfer ballast water from tanks overboard to the sea through a sea chest. This shore treatment method requires addition of a discharge line leading to a new manifold on deck.

From the deck manifold, flexible hoses or specially designed cargo loading arms transport the ballast water across to a shore-side manifold. Shore-based booster pumps move the ballast water into large storage tanks. Via a second smaller pumping system, the storage tanks feed into the municipal sewage system at a rate that the sewage treatment plant can accommodate. These modifications are described in further detail below, and example installation specifications are given for two subject vessels in Appendix E.

5.2 Method A: Vessel Modifications

Vessels using this alternate method will require modifications to the ballast systems. In some cases, vessels might need ballast pump upgrades, but in the four specific cases examined here, engineering analysis determined that existing pump capacity would suffice (See Appendix G). A deck manifold is added to allow for connection of the ship to a shore facility. Different existing ballast systems will result in different modifications. For instance, the intermediate to large capacity 1000' Laker (Vessel One) requires a common rail header, port and starboard, to integrate the ballast discharge from the individual pumps. Vessels Two, Three, and Four, with common pumps aft will require a riser to bypass the overboard discharge. This work assumes the existing ballast pump systems remain. The details of two different designs are included in Appendix G.

5.3 Method A: Ship-to-Shore Connection – Two Options

5.3.1 Method A: Option #1 – Transfer Hoses with Shore Cranes

The high transfer rates for ballast water requires large sized hoses, and normal water transfer hoses will not work. A brief survey of vendors reveals the largest common water transfer hose is 10" or 12" diameter, depending on vendor (Goodyear Rubber Products, Updated 2010, Accessed June 7, 2011; Gates Corporation, July 30, 2009; Goldstein-Schwartz, June 7, 2011). This option requires specially manufactured hoses commonly used in the offshore oil and gas industries. Four transfer hoses to connect the vessel to the shore connection are needed for a 16" diameter discharge ballast system for the large capacity 1000' Laker Class vessel. Also, this requires a marine hose-handling crane, specially engineered and constructed hose saddles, and a specially engineered and fabricated hose fairlead on each side of the vessel, outboard of the off-loading manifold.

There are at least two methods of handling marine cargo hoses.

1. The hoses are all bundled together and attach as one unit.
2. The hoses are handled independently.

The hose-handling crane should also have a large enough reach and maneuverability to easily position the hoses on the ship manifold. The assumed equipment is a telescoping boom crane with a 40' to 60' maximum radius (Hydra Pro Crane, June 7, 2011).

5.3.2 Method A: Option #2 – Loading Arms

A marine loading arm combines a crane and hose into a single unit (Figure 3). The crane supports the hose and allows easy positioning of the specially designed swiveling hose flanges to connect to the vessel. The marine loading arm offers a very clean and less manually intensive option (compared to hoses) for handling hoses.

Marine loading arms are available in hose diameters up to 24", but the largest sizes are very costly (Emco Wheaton, June 13, 2011; Connex SVT, June 9, 2011). The more cost-effective option is a hose diameter of 16". At 16", the flow rates for the large 1000' Laker Class vessel require four loading arms.

Depending on vessel size and flow rate, ports can choose from the two options for the ballast transfer connections. Smaller vessels could use one to two hoses (or arms). The larger vessels, with a flow rate above 35,250 gpm (8006 m^3/hr), require up to four 16" diameter hoses (or arms). Both configurations feed into dockside manifolds and booster pumps to sustain the vessel's required ballast transfer rate. This type of permanent infrastructure would require a vessel to be moored with respect to the ballast transfer connection rather than to the facility's cargo loading arrangement.

Source: Kanon Loading Equipment, B.V. (April 28, 2010)

Figure 3. Example marine loading arm.

5.4 Method A: Shore-side Facilities

5.4.1 Method A: Facility Location

Many of the vessels on the Great Lakes discharge a massive amount of ballast water. In this example, a cargo loading facility contracts with the municipal sewage system to treat ballast water at a specified flow rate. The specified flow rate must meet the operations requirements for the cargo loading facility but not overwhelm the municipal sewage treatment plant. To meet these requirements, the system requires a large storage facility. This storage facility acts as a massive buffer to accommodate the difference in flow rate (from vessel to shore, and storage to municipal system). Unfortunately, large facilities require large amounts of land, and this land is typically not very affordable in an urban city near the waterfront, nor readily available in the industrial areas surrounding major bulk-loading facilities. In order to minimize property expenses, the facilities consist of two locations. The first location at the loading facility houses the booster pumps and connection equipment. The booster pumps pump the ballast water to the second location, where the storage tanks, tank discharge pumps, and metering valves are located.

The location of the storage tanks completely changes with each specific cargo-loading facility and port area, depending on population density, local zoning, and property prices. The location assumed for the storage tanks is located 0.50 mile away (2640'), with a geographic elevation change of 30'.

5.4.2 Method A: Transition Piping

The transition piping must carry a large amount of ballast water from the shore side to the remote area where the storage tanks are located. The route from the shore-side pumps to the storage tanks most likely crosses multiple municipal utilities and requires a set of pipelines buried in parallel with the existing utilities (as best possible). The parallel pipes allow flexibility to avoid conflict with existing utility systems along the piping route. Pipe material could be ductile iron, polyvinyl chloride pressure (PVC) pipe, or fusion-welded high-density polyethylene (HDPE). At an inner pipe diameter of 24", up to four pipes in parallel are required to achieve acceptable flow rates and small enough friction losses. Design specifications are available in Appendix E, Section E.2.1.

Pressure drop in piping is frequently measured as the pressure resulting from a column of water with a given "head" height. Vertical changes in height produce a head equal to the height change. Friction head refers to the pressure drop purely due to the internal friction of the pipe. The calculated friction head loss for the transition piping is 36.3'. The head loss from assumed elevation change is 30' (9.14 m), with an additional 58.0' (17.7 m) for the storage tank height (88' (26.8 m) total). Total head loss for the whole system, including friction, is 124.3' (37.9 m), 53.88 psi (371.8 kilopascals (kPa)). This is within the expected range for the given flow rate of ballast water.

5.4.3 Method A: Booster Pumps

The booster pumps must generate enough pressure to move the required volume of water from the dock over to the remote storage location, and then fill the storage tanks. Estimated pressure loss in the system is 53.88 psi (371.8 kPa). The system uses four pumps working in parallel, with a fifth spare pump. (See Appendix E for detailed specifications.) With this arrangement, any one pump can undergo maintenance without affecting service. Each of the four pumps needs a rated power of approximately 504 hp (376 kW), 2016 hp (1503 kW).

A similar set of discharge pumps installed at the storage tank facility discharges the ballast water to the municipal sewer system, at a pre-determined, and adjustable, metered rate. These pumps will be much smaller as they do not have the same head to overcome and do not need to have the same high flow rate that the larger booster pumps need to accommodate.

5.4.4 Method A: Storage Tanks

The storage facility is located 0.50 mile from the loading facility. The storage facility is owned by the loading facility, which contracts with the municipal sewage system to treat ballast water at a specified flow rate. As mentioned above, the storage facility must act as a massive buffer to accommodate the difference in flow rates.

A preliminary estimate of the required storage tank capacity assumes that the storage tanks must hold all the ballast water from the largest vessel (large capacity 1000' Laker Class). Research investigated the standard flow rates of sanitary treatment systems for the cities of Green Bay, Chicago, Milwaukee, Cleveland, and Duluth and found daily flow rates anywhere from 39,000 gallons per hour (gal/hr) (147.63 m^3/hr) to 195,000 gal/hr (738.15 m^3/hr). The vessel discharge would be prevented from causing the sanitary treatment system to exceed its daily flow capacity. Based on this, the discharge rate to the sewage system is assumed at 195,000 gal/hr (738.15 m^3/hr), since it will provide a minimal required tank buffer capacity. At this rate, the sewage system takes 7.8 days to accept all the ballast water at the storage facility.

For loading facility operations, the assumed worst-case scenario is one large 1000' Laker discharges ballast over a period of about 7 hours. Twelve hours after the first vessel, a second large 1000' laker arrives and does the same. No further large 1000' Lakers arrive after the second vessel until the storage tanks are empty. The size of the ballast storage system sustains this rate of port activity. (Full details of specifications and assumptions are shown in Appendix E, Section E.2.3.3.)

With these assumptions for port operations, the ballast storage system requires a total storage capacity of 36.6 million gallons. One important point is that the storage system capacity limits storage facility operations. From the point when the first 1000' laker begins to discharge ballast, the storage facility requires a full 188 hrs (7.8 days) to clear away all ballast from the two 1000' vessels. This indicates the limit on loading facility operations that the sewage treatment option imposes.

Total storage capacity is achieved by an array of several storage tanks. The individual storage tanks are sized to meet the ballast capacity of the smallest Class vessel (3 million gallons (11,511 m^3)). The intent is to fit all ballast water for the smallest ship in a single storage tank. The advantage of this approach is that it leaves the other tanks empty for maintenance. Based on this requirement, an array of 13 tanks is used; the size of each tank is 91' (28 m) diameter x 58' (18') height. Table 8 summarizes tank sizes.

Table 8. Summary of ballast storage tanks.

Individual Tank Diameter	91.0'	27.73 m
Individual Tank Height	58.0'	17.65 m
Individual Tank Capacity	2,816,393 gal (376,497 ft^3)	138,596 m^3
Number of Tanks	13	13
Total Storage Capacity	**36,613,108 gal**	**138,596 m^3**

It is desirable to fill one storage tank at a time; this permits maintenance when tanks are not used, without shutting down the entire system. This capability and other operation needs require automatic control valves for the piping distribution system. An automated control system measures the current level of each storage tank and completely fills each tank before diverting flow to the next tank. This system also controls the sequence for emptying each tank into the sewage system.

5.4.5 Method A: Sewage System Outlet

The storage tanks feed ballast water into the sewage system at a controlled rate. This rate depends on the capacity of the individual city's sewage treatment plant. Research investigated the standard flow rates of sanitary treatment systems and found daily flow rates anywhere from 39,000 gal/hr to 195,000 gal/hr. This suggests the ballast discharge rates could overwhelm many existing municipal sewage treatment systems. The economic and political impacts of whether a municipality would upgrade the sewage treatment facilities to accommodate this new demand are beyond the scope of this work.

Given the high variability in flow rates, the calculations use an assumed maximum flow rate of 195,000 gal/hr (738.15 m^3/hr) into the treatment system. This assumption neglects any outside influences on the sewage system capacity, such as storm surge water. Variable speed pumps and a flow meter control the discharge rate into the sewage system. The flow meter also tracks the discharge volume for billing and recording purposes.

The outlet pumps from the storage facility are relatively small, as they do not have a large pressure head or large flow rate. The discharge rate is roughly 195,000 gal/hr (738.15 m^3/hr). The connection to the municipal sewage system includes an elevation change of 20.0' and a piping length of 100'. This assumption represents a reasonable worst-case scenario for sizing the outlet pump. It requires the pump to develop a total head of 20.30' (6.19 m), achieved by one pump rated at 23.5 hp (Goulds Pumps, August 19, 2011).

5.4.6 Method A: Support Infrastructure

The ballast storage facility requires minimal support infrastructure, with all major activity located back at the vessel loading dock. The storage facility requires electric power, a security fence, and a tank level control system, and some small maintenance and storage buildings. The largest item to consider is the automated flow control system at the storage facility. The automated system directs incoming ballast water to individual storage tanks, and it controls the sequence for emptying tanks into the sewage system. This automated system also includes a link to a remote monitoring and control station back at the vessel loading dock.

The vessel loading dock may already have sufficient infrastructure to accommodate ballast transfer operations. However, if there is no existing infrastructure, the dock requires the following systems. The infrastructure at the vessel loading dock includes a small pump/operations building to house the pumps and monitor ballast operations on the loading dock and at the storage facility. The same building contains a garage for hose transport vehicles (if any) and storage for the ballast transfer hoses. There is also a small pipe maintenance shop. (Specifications are in Appendix E Section E.2.5.) The total support infrastructure is small, but not insignificant.

5.5 Method A: Cost Estimate

5.5.1 Method A: Installation Costs

Table 9 summarizes the installation cost estimate for the municipal sewage treatment option. Costs are divided into the costs incurred by the ship and by the loading facility. (Detailed cost estimates are calculated in Appendix E, Section E.3.1.) The loading facility has a much higher installation cost than the ship.

Table 9. Installation cost estimate: municipal sewage treatment option.

Cost Item	Ship Costs	Loading Facility Costs
Ship Modifications	$1,149,575	--
Ship-to-Shore Connection	--	$2,306,312
Shore Facilities and Equipment	--	$48,319,601
Total	**$1,149,575**	**$50,625,913**
Note: Table 9 assumes loading arms, and large capacity 1000' Laker		

5.5.2 Method A: Service Costs

The economics of how the loading facilities provide shore-side ballast water transfer and storage must also be calculated. How they are applied has not been determined, particularly as many cargo loading facilities are only part of a frequently linked supply chain that connects mines, railroads, and end receivers. The service costs that a loading facility may charge for use of their transfer and storage services are estimated. The service fee must cover initial costs and operational costs. The initial costs include construction of the BWTF, permitting, and training personal. Operational costs include employees to manage the BWTF, electric power, communications, sewage connection, etc.

The municipal sewage treatment plant will charge to accept the ballast water. Research investigated the industrial waste water treatment charges from the cities of Green Bay, Chicago, Milwaukee, and Cleveland. The rates varied from $1.55/1000 gallons ($0.41/m^3) to $4.96/1000 gallons ($1.31/m^3). This disparity in treatment cost could make some ports more costly than others.

There are costs for ongoing maintenance of the system. Finally, the loading facility will want to insure the entire facility, which requires insurance premiums. Detailed estimates for these costs are given in Appendix E, Section E.3.2. The total costs are summarized in Table 10.

Table 10. Service cost estimate: municipal sewage treatment option.

Service Charge		$13.17	USD/1000 gal ballast water		
		$3.48	USD/m^3 ballast water		
Example Costs				**Annual Costs**	
Vessel Class	**Ballast Capacity**		**Process Charge**	**Trips**	**Cost (M USD)**
	gal	**m^3**			
Vessel One: Intermediate to Large Capacity 1000' Laker	9,132,164	34,569	$120,300	43	4.14
Vessel Two: Large Capacity 1000' Laker	16,416,440	62,143	$216,258	39	6.74
Vessel Three: Older, Small Capacity 700' – 800' Laker	3,152,101	11,932	$41,523	72	2.40
Vessel Four: Newer, Intermediate Capacity 800' – 900' Laker	6,369,981	24,113	$83,913	40	2.69

Notes:
1. Annual cost assumes an average of 80% of ballast capacity discharged for each trip.
2. Annual trips based on: "Ballast Water Treatment, Laker Practicability Study – Volume I: Present Conditions".

5.6 Method A: Facility Practicability

Design calculations and cost estimates show that the municipal sewage treatment option is extremely expensive and not feasible for these ballast capacities and flow rates. Because of the high treatment volumes, the cost will probably be too high for this to be an attractive option for ship owners. The rate of discharge to the sewage system of 195,000 gal/hr (738.15 m^3/hr) is anywhere from 5 percent to 25 percent of the average daily flows for these systems. Fortunately, most existing municipal systems currently use chemical dosing (i.e., sodium hypochlorite) to disinfect and eliminate organisms. The sewage treatment plants need to ensure that the necessary pre-treatment technology is in place to effectively process ballast water.

Other issues for this option are that finding space to store 36.6 million gallons (138,596 m^3) will be difficult and expensive. Furthermore, municipal sewer systems may not actually be able to remove the invasive species. If not, the loading facility or sewage treatment plants would need some form of pre-treatment technology to effectively process ballast water.

The infrastructure required to support this BWT option is disruptive to the waterfront, as extensive piping is required. Excavation for the piping in heavy industrialized areas could also encounter contaminated soils, which add to the cost of installation. The assumed discharge rate to the sewage system requires a large gap between ship arrivals to allow the storage system to empty sufficiently before resuming operation. All these factors compound to show that at large flow rates, municipal sewage treatment of significant quantities of ballast water is not practical.

6 ALTERNATIVE BWM METHOD B: DEDICATED BWTF

6.1 Method B: General System Description

A dedicated BWTF requires the same ship modifications and ship-to-shore connections as described in Section 5. From the deck manifold, either hoses or loading arms carry the ballast water across to a shore-side manifold. After the ship-to-shore connection, the system arrangement and requirements change. A dedicated BWTF can be located much closer to the ship/shore connection, and more easily integrated into the loading facility's existing infrastructure. Buffer tanks for a dedicated BWTF could be smaller, depending on any necessary "hold time" and whether the BWTF processes all ballast water as it leaves the ship; the tanks act as a temporary buffer for surge capacity. Due to the smaller tanks, faster treatment rate, and closer location, the dockside booster pumps are sized much smaller relative to the waste water treatment option.

Ballast water discharges from the ship through a discharge manifold on either port or starboard side to a pump house located on the dock. From the pump house, four 16" diameter pipes convey ballast water to the BWTF and discharge back to the harbor.

6.2 Method B: Shore-side Facilities

6.2.1 Method B: Transition Piping

The transition piping must carry a large amount of ballast water a short distance from the dock over to the manifolds at the buffer tanks, and then into the BWTF. The assumed pipe length from the booster pumps to the BWTF is 500'. To minimize costs, the majority of the pipe length can be pressure-rated PVC or HDPE that is fusion-welded.

The pipes should be large enough for the largest flow rate with minimal friction losses. A series of four 16" inner diameter pipes meets the requirements. The reason for using multiple smaller pipes is to provide flexibility to work around the existing utilities and provide some redundancy in case of a problem with a pipe. Preliminary estimates conclude the friction head loss is 5.5' (1.7 m) The assumed head loss from ground-level elevation change is 10' (3.0 m) and 20' (6.1 m) for the height of the storage tanks (30' (9.1 m) total). Total pressure head for the whole system, including friction, is 38.29' (11.67 m). This is a much smaller head requirement than the BWTF described in Method A. The buffer tanks only need a capacity of 300,000 gal (1,135.6 m^3) each. These three tanks are roughly 50' (15 m) in diameter and 22' (6.7 m) high to allow some freeboard when full (Superior Tank Company, Inc., June 9, 2011).

6.2.2 Method B: Booster Pumps

The booster pumps must move the water from the dock, over to the control manifolds at the buffer tanks, and on into the treatment facility. The estimated pressure loss for the system is 17 psi (117 kPa.) Four pumps are used, with a fifth pump as a spare. (See Appendix F, Section F.1.2 for detailed specifications.) With this arrangement, any one pump can undergo maintenance without affecting service. Given this arrangement, each pump has an estimated installed power of 157 hp (117 kW), (628 hp (468 kW) for four pumps). The pump curve is given in Appendix F, Figure F-2.

6.2.3 Method B: Buffer Tanks

The buffer tanks serve a very different purpose from the storage tanks described for Method A in Section 5.4.4. The buffer tanks hold a much smaller volume of ballast water and for a shorter period. We assume the BWTF processes water at the same rate as it discharges from the largest vessel (Large 1000' Laker

Class). This is consistent with what is required for an onboard treatment system. Another assumption is that a new vessel discharges its ballast over a 7-hr period (a single vessel requires 6.62 hrs to discharge all ballast).

With the increased treatment rate, the BWTF only requires storage for a short period as a buffer for the system. (Full details of specifications and assumptions are in Appendix F, Section F.1.3.) This system uses two equally sized tanks to provide some redundancy during normal operations (Superior Tank Company, Inc., June 9, 2011). This gives additional storage capacity in the event of equipment problems in the treatment system. This system has roughly 723,000 gal (2,736.8 m^3) of buffer storage, which allows a 17-minute buffer at full capacity. Table 11 summarizes tank sizes.

Table 11. Summary of ballast buffer tanks.

Individual Tank Diameter	50.5'	15.2 m
Individual Tank Height	24.1'	7.35 m
Individual Tank Capacity	361,544 gal	1,368.6 m^3
Number of Tanks	2	2
Total Storage Capacity	**723,088 gal**	**2,737.2 m^3**

6.2.4 Method B: Treatment Plant

The BWT plant uses the same technology as the ship-based filtration/UV BWT system, only mounted on a land-based facility.[2] The facility is based on the UV treatment technology. This analysis does not include an evaluation of the permitting that would be required. The treatment facility would have to have an NPDES permit, and there are significant upfront, as well as operational, costs associated with such enterprises. The analysis of these additional costs are beyond the scope of this work.

The BWT system is modular with multiple treatment units. The treatment plant requires a total flow rate of 52,000 gpm (11,810 m^3/hr) for one ship. This is achievable by using the two units of the filtration/UV technology system used on the Large Capacity 1000' Laker. Each BWT unit is capable of shutting down and isolating individual filters or UV reactors. This permits maintenance of individual parts while still operating the rest of the unit at a reduced capacity. Table 12 summarizes the BWT plant properties.
The BWTF has by-products that also require treatment. The filters on the BWT units require back-flushing to clean them periodically. On a vessel, back-flush water discharges back into the water at the same location it is taken in. This methodology works because the organisms return to their native habitat (the same lake and lake area). However, the land-based BWT plant processes water brought in from any location, which may include invasive species requiring treatment that is more intensive (Hyde Marine, June 15, 2011). The filter back-flush water discharges to the municipal sewage system for treatment. This back-flush flow is several orders of magnitude less than the amount flowing from the ship and should not overwhelm local sewage treatment plants.

[2] For purposes of this study, UV-based systems were assumed to meet the ballast water discharge standard, even though in usual water treatment practice UV is used to render organisms incapable of reproduction, not to kill or remove organisms.

Table 12. Summary of BWT units.

BWT Unit	Per Unit	System Total
Number of units	--	2
Required Capacity	--	52,000 gpm 11,810 m^3/hr
Provided Capacity	13,200 gpm 2,998 m^3/hr	52,800 gpm 11,992 m^3/hr
Normal Electric Demand	234 kW	936 kW
Maximum Electric Demand	342 kW	1,710 kW
Normal Back-flush Flow	198 gpm 45 m^3/hr	792 gpm 180 m^3/hr

6.2.5 Method B: Support Infrastructure

The buffer tanks include manifolds with an automated valve control system which directs incoming ballast water to BWT units or the individual buffer tanks as needed. From the buffer tank manifolds, the ballast water flows to the filters and UV reactors. The treatment system includes a link to a remote station at the vessel loading dock. BWT treatment operators control and monitor the entire system, buffer tanks, and BWT units from the loading dock.

For purposes of this study, drawings and cost estimates of a dedicated new loading facility are developed. The treatment facility site includes minor office space, maintenance facilities, and the treatment plant along with associated parking. The required building space is approximately 5,000 ft^2. There are two parking stalls and one handicap accessible space for the employees. The access road/drive to the office/treatment facility is a 24' wide asphalt road. This infrastructure assumes a new loading facility. To install the BWTF at an existing loading facility, significant infrastructure cost savings are achieved. The BWT plant and associated equipment are still required. These occupy approximately 4,300 ft^2.

6.3 Method B: Cost Estimate

6.3.1 Method B: Shore Facility Costs

For civil infrastructure and site work, the facility includes two 300,000-gal water storage tanks, a 5,000 ft^2 office/maintenance/BWT plant building, two large distribution manifolds with valves, and four parallel 16" ballast water conveyance pipes with a riprap-lined outfall pad.

Table 13 includes a rough order-of-magnitude cost for these features. These costs are based on RS Means Cost Data Catalog (2011). Detailed cost estimate available in **Appendix F**, Section **F.2.1**.

Table 13. Installation cost estimate: dedicated BWTF option.

Cost Item	Costs: New Build	Costs: Existing Facility
Building for Office/BWT Plant	$2,248,620	$--
Manifolds, Piping System, and other Machinery	$2,808,842	$2,808,842
BWT Plant	$5,594,288	$5,594,288
Ship-to-Shore Connection	$2,698,385	$2,698,385
Other Project Costs (Management, Contingency, Misc.)	$5,456,550	$5,456,550
Shore Facility Estimated Total Cost:	**$18,806,685**	**$16,558,065**
Note: Table 13 assumes loading arms and large capacity 1000' Laker		

6.3.2 Method B: Service Costs

Costs must be absorbed. Loading facilities would not necessarily provide shore-side BWT free of charge. Service fees must cover initial and operational costs. The initial costs include construction of the BWTF, permitting, and training personal. Facility operational costs include two full-time employees to manage the BWTF. The municipal sewage treatment also charges to accept the back-flush water. There are costs for ongoing maintenance of the system and utilities. Finally, the loading facility owner will want to insure the entire facility, which requires insurance premiums. Table 14 lists estimated service costs. Detailed calculations of service cost estimate available in Appendix F, Section F.2.2.

Table 14. Service cost estimate: dedicated BWTF.

Service Charge	$3.13	USD/1000 gal ballast water
	$0.83	USD/m^3 ballast water

Example Costs				Annual Costs	
Vessel Class	**Ballast Capacity**		**Process Charge**	**Trips**	**Cost**
	gal	**m^3**			
Vessel One - Intermediate to Large Capacity 1000’ Laker	9,132,164	34,569	$28,692	43	$980,000
Vessel Two - Large Capacity 1000’ Laker	16,416,440	62,143	$51,579	39	$1,600,000
Vessel Three - Older, Small Capacity 700’ – 800’ Laker	3,152,101	11,932	$9,904	72	$580,000
Vessel Four - New Intermediate Laker	6,369,981	24,113	$20,014	40	$640,000

Notes:
1. Annual cost assumes an average of 80% of ballast capacity discharged for each trip.
2. Annual trips based on: “Ballast Water Treatment, Laker Practicability Study – Volume I: Present Conditions” for 2010 trips.

6.4 Method B: Facility Practicability

The land-based BWTF is generally feasible if there is adequate land available to provide the necessary facility infrastructure. Finding the necessary land to site the BWTF near the loading facility can be a challenge at some ports, though various facility configurations will optimize space limitations. The largest cost of the land-based BWTF is the initial materials, treatment system equipment and construction costs. In the long term, operation and maintenance costs are relatively minimal.

A project plan outline with a Gantt Chart is provided in Appendix F, Section F.3. The plan identifies critical steps and estimated time lines for detailed engineering and design, permitting, bid process, materials and equipment purchases, and phases of construction and testing. Total estimated project time is roughly 2 years. If shore based treatment were determined to be the desired approach, a large number of facilities, in multiple locations, would need to be built simultaneously. Such coordinated, wide ranging and costly effort poses significant challenges.

7 CONCLUSIONS

7.1 Summary of Vessel Installation Costs

The installation and operation costs vary from vessel to vessel. The differences in cost are based on:

1. Vessel design.
2. Cargo capacity.
3. Age of the vessel.
4. BWT system installed.

Table 15 shows that the cost for installing a BWT system varies (rounded) from $3,457,000 to $11,619,000.

Table 15. Summary of vessel installation costs.

Vessel	BWT 1: Filtration and UV	BWT 2: Ozone
Vessel One: Intermediate to Large Capacity 1000' Laker	$10,951,000	$7,731,000
Vessel Two: Large Capacity 1000' Laker	$11,619,000	$6,292,000
Vessel Three: Older, Small Capacity 700' – 800' Laker	$8,897,000	$3,457,000
Vessel Four: Newer, Intermediate Capacity 800' – 900' Laker	$7,944,900	$6,331,000

The cost estimates provided are not normalized. The cost to install a BWT should include a comparison with the cargo shipped. A method to normalize the cost is to include the size of the vessel. A good representation of the size and cargo capacity is the deadweight. See Table 16.

Table 16. Normalized estimated cost.

Vessel	BWT 1: Filtration and UV	BWT 2: Ozone
Vessel One: Intermediate to Large Capacity 1000' Laker Deadweight 62,400 lt	$175/lt	$124/lt
Vessel Two: Large Capacity 1000' Laker Deadweight 49,641 lt	$130/lt	$70/lt
Vessel Three: Older, Small Capacity 700' – 800' Laker Deadweight 25,600 lt	$348/lt	$96/lt
Vessel Four: Newer, Intermediate Capacity 800' – 900' Laker Deadweight 39,600 lt	$201/lt	$160/lt

The ozone system appears to be the less expensive than the filtration/UV system when compared using normalized values. The installation of the ozone system appeared to take up less space. The system components can be located in various locations on the vessel and still be effective.

7.2 BWT Systems Study Results

The study looked at 20 BWT systems comprised of several different treatment technologies. The 20 systems had received IMO approval. Not all the approved systems would properly operate in the Great Lakes from either the cold water or low salinity levels. Some vendors are researching and testing devices for operation in the Great Lakes. Conclusions from this study include the following. The testing needs to

include the unique operations for the vessel's operations. This includes the short duration of the vessel trips. Two technologies that would not require purchase and storage of additional chemicals for treatment are:

1. Filter/UV treatment.
2. Ozone injection.

Filter/UV and ozone treatment were used for this study, as they cover examples of both non-chemical and chemical treatment. The design installation and cost estimates were made on a wide range of assumption. More detail work should be done to better understand the installation and cost to install other treatment technologies and BWT systems.

7.3 Shore-side Treatment

Two different shore-side discharge treatment methods are studied: municipal treatment and dedicated system. (This work did not include taking on treated ballast water at a cargo discharge port.) Both of the shore-side discharge treatment concepts have been considered before. Both require building significant infrastructure at the cargo loading berth (and port area for the municipal treatment). The dedicated system appears to be a better option over municipal treatment. The dedicated system can be designed for vessel operation at a specific port. Municipal treatment will require additional infrastructure to tie the berth into the municipal system. The issues associated with permitting, including discharge and infrastructure approval and construction, is not covered in this report. Vessels wanting to use these concepts would have to operate only on routes with shore-side treatment, and treatment facilities would have to be opened at all ports at the same time. Previous studies have shown that some vessels do operate principally from one port. A dedicated shore-side treatment system may be a viable solution in a limited number of cases.

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APPENDIX A VESSEL ONE (INTERMEDIATE TO LARGE CAPACITY 1000' LAKER), BWT SYSTEMS: SUPPORTING DOCUMENTS

A.1 Vessel One, BWT System 1

A.1.1 Vessel One, BWT System 1: Electrical Loads Analysis

The vessel does not have the electrical power capacity to operate the BWT system. New electrical diesel generators are added to power the BWT system. The BWT system requires an additional 1,816 kW; see Table A-1.

Table A-1. Vessel One, BWT System 1: electrical loads summary.

	#	power (kW)	total (kW)
UV Reactors	18	75	1,350
Backwash Pumps	18	25	450
Ventilation	1	15	15
Lighting	1	1	1
		Total	**1,816**

A.1.2 Vessel One, BWT System 1: Deadweight Analysis

The light-ship weight of the vessel increases because of the addition of the BWT system, generator and electrical system installation, and ancillary system changes. The weight change decreases the cargo-carrying capacity of the vessel. Table A-2 contains the weight change summary.

Table A-2. Vessel One, BWT System 1: weight estimate.

	#	weight (lb)	total (lb)
BWT Systems	18	6,934	124,812
piping/foundations	+25%	124,812	31,203
Generators	2	19,640	39,280
switchboards/wiring	+10%	39,280	3,928
enclosures + structure	+50%	39,280	19,640
auxiliary systems	+25%	39,280	9,820
		Total (lb)	**228,683**
		Total (LT)	**102.1**

A.1.3 Vessel One, BWT System 1: Cost Estimate

The vessel will have to be modified for the installation of the BWT. Structural changes and existing system will have to be modified. The modification will require accesses to be cut and repaired. The summary cost is $10,950,534; see Table A-3.

A.1.4 Vessel One, BWT System 1: System Installation Drawings

The vessel structure and mechanical system will be modified for the BWT systems. The proposed structural and piping changes are shown in Figure A-1.

Table A-3. Vessel One, BWT System 1: cost estimate summary.

Preliminary Cost Estimate Summary: Shipboard Filtration & UV BWT System									
SWBS No.	**Item Description**	**Labor Hours**	**Material & Services @ Cost ($)**	**Subcontracts @ Cost ($)**	**Labor Cost @ $70/Hr**	**Material & Services w/17% Mark-up ($)**	**Subcontracts w/8% Mark-up ($)**	**Item Total Costs**	**Percent of Total Cost**
000	Project Management & Admin	484	$334,634	$--	$33,869	$391,521	$--	$425,390	3.88%
100	Structure	8321	$93,130	$--	$582,461	$108,962	$--	$691,423	6.31%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	13895	$714,455	$--	$972,630	$835,912	$--	$1,808,542	16.52%
400	Electronics & IC Systems	954	$19,600	$--	$66,797	$22,932	$--	$89,729	0.82%
500	Auxiliary Systems	9614	$93,322	$3,575,355	$672,986	$109,186	$3,861,383	$4,643,555	42.40%
600	Outfitting	963	$14,022	$--	$67,424	$16,406	$--	$83,830	0.77%
700	Mission Specific Equipment	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	108	$32,648	$616,000	$7,526	$38,198	$665,280	$711,005	6.49%
900	Shipyard Support Services	6283	$241,920	$95,200	$439,824	$283,046	$103,768	$826,638	7.55%
	Contingency @ 18%							**$1,670,420**	**15.25%**
	Based on Concept Design Level								
	Totals for All Items	**40622**	**$1,543,731**	**$4,286,555**	**$2,843,517**	**$1,806,165**	**$4,630,431**	**$10,950,534**	**100%**

MATERIAL SCHEDULE

SERVICE	SIZE	PIPE	TAKEDOWN JOINTS: MATERIAL	TAKEDOWN JOINTS: GASKETS	TAKEDOWN JOINTS: BOLTING	FITTINGS	VALVES: BODY	VALVES: TRIM	REMARKS
BALLAST WATER	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28	BUTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS	

SYMBOLS LIST

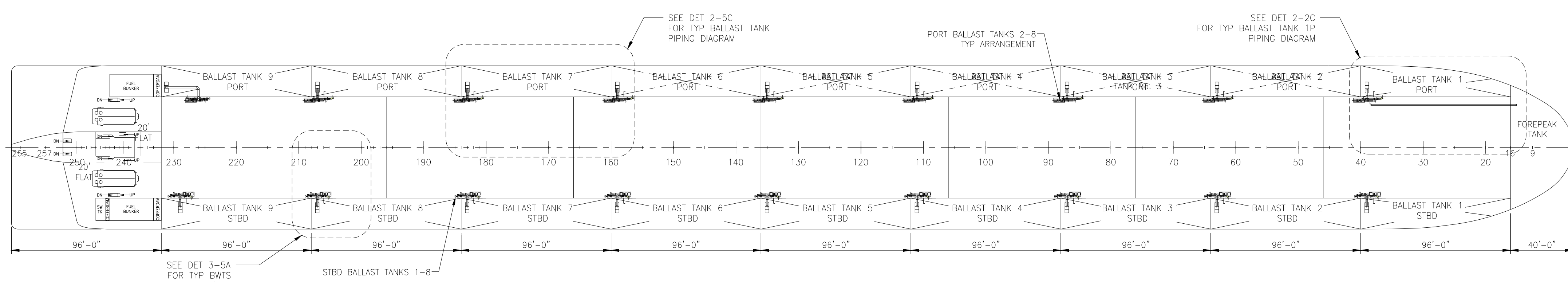
	NEW PIPE W/ FLOW DIRECTION
	EXISTING PIPE W/ FLOW DIRECTION
	BUTTERFLY VALVE REMOTELY OPERATED (ELEC THROTTLING) W/ CAPABILITY OF MANUAL OPERATION
	BUTTERFLY VALVE REMOTELY OPERATED (AIR OPEN OR CLOSE) W/ CAPABILITY OF MANUAL OPERATION
	BUTTERFLY VALVE
	GLOBE VALVE
	BHD/DECK PENETRATION
	SWING CHECK VALVE
	PRESSURE GAUGE
	DRESSER COUPLING W/ ANCHOR BOLTS
	CROSSING PIPES CONNECTED
	CROSSING PIPES NOT CONNECTED
	SEACHEST
	SUCTION BELLMOUTH
BWTS	BALLAST WATER TREATMENT SYSTEM

MAJOR EQUIPMENT LIST

QTY.	ITEM	MAKE	MODEL	CAPACITY	DRIVE/NOTES
18	SWING CHECK VALVE	–	5"	–	–
18	SWING CHECK VALVE	–	10"	–	–
18	BUTTERFLY VALVE	–	10"	–	–

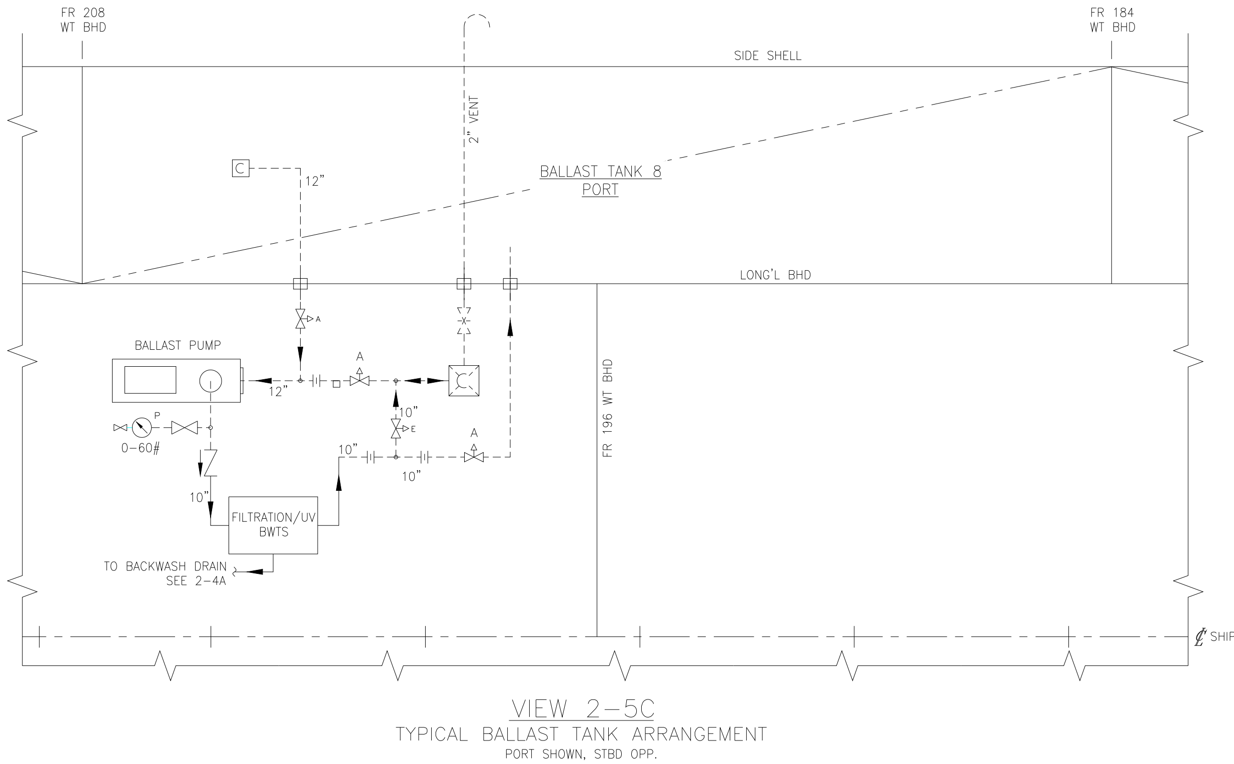
PUMP LIST

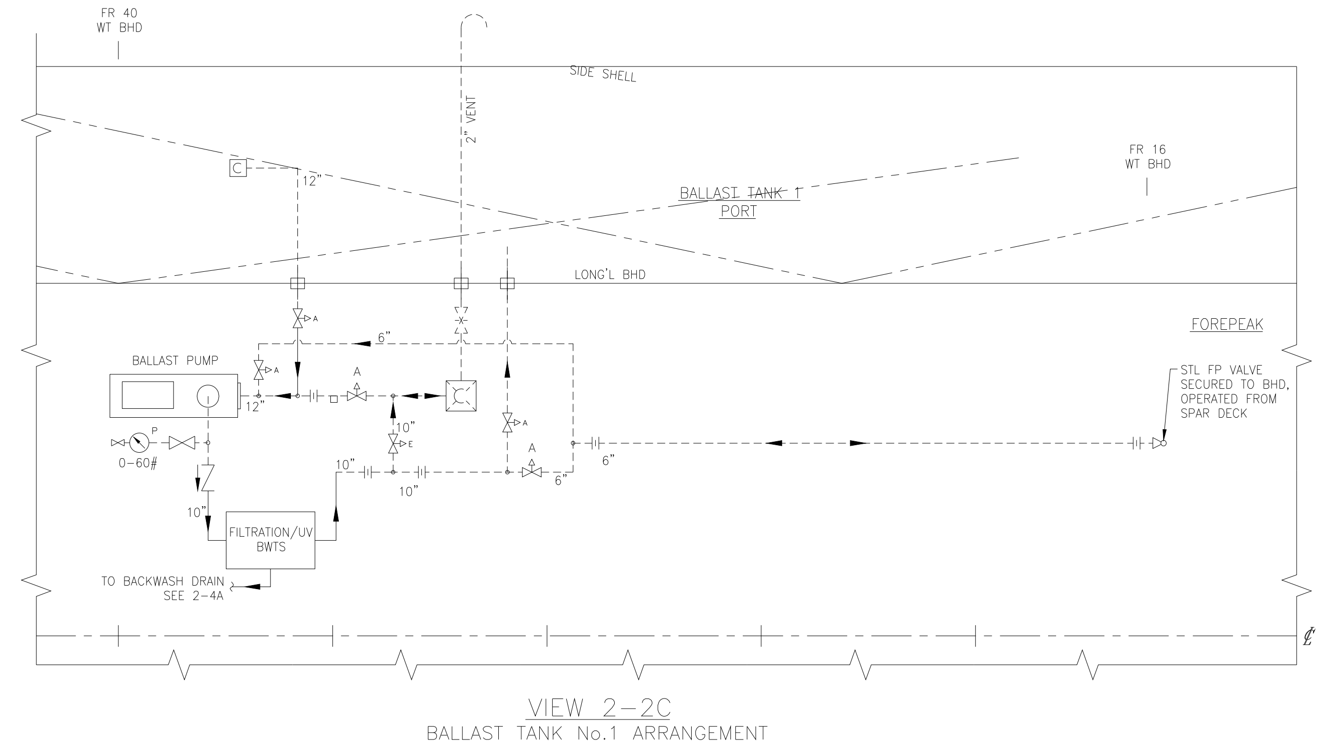
QTY.	SERVICE	TYPE	MODEL	CAPACITY	DRIVE
–	–	–	–	–	–



KEY PLAN 1-4A
INTERMEDIATE TO LARGE CAPACITY 1000' LAKER
TANK ARRANGEMENT

Figure A-1. Vessel One, BWT System 1 (filter/UV BWT System): piping diagram and general arrangement (1 of 3).





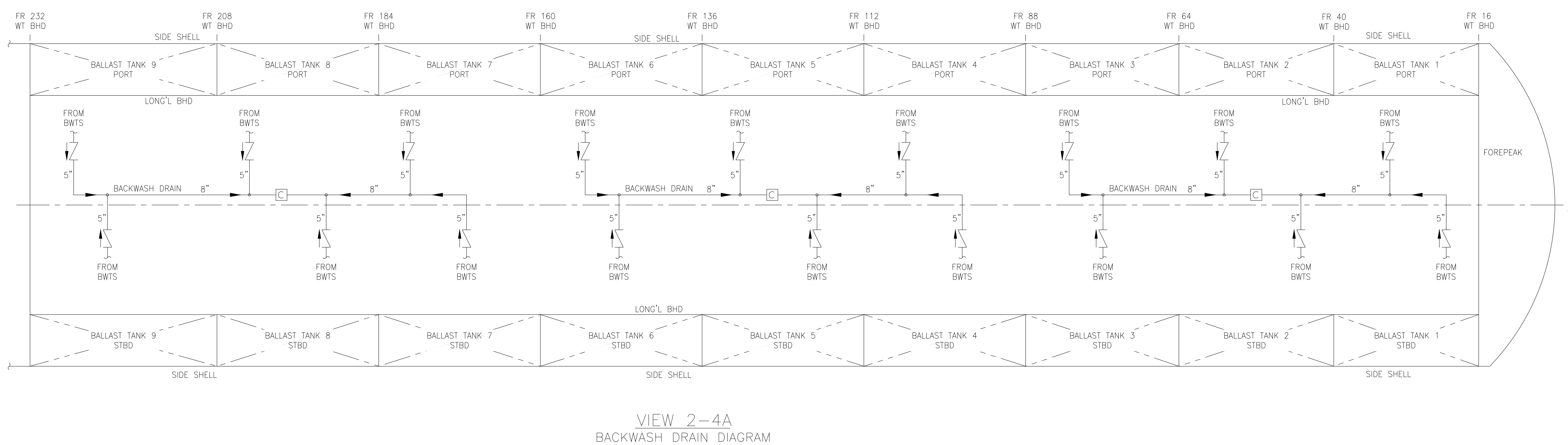
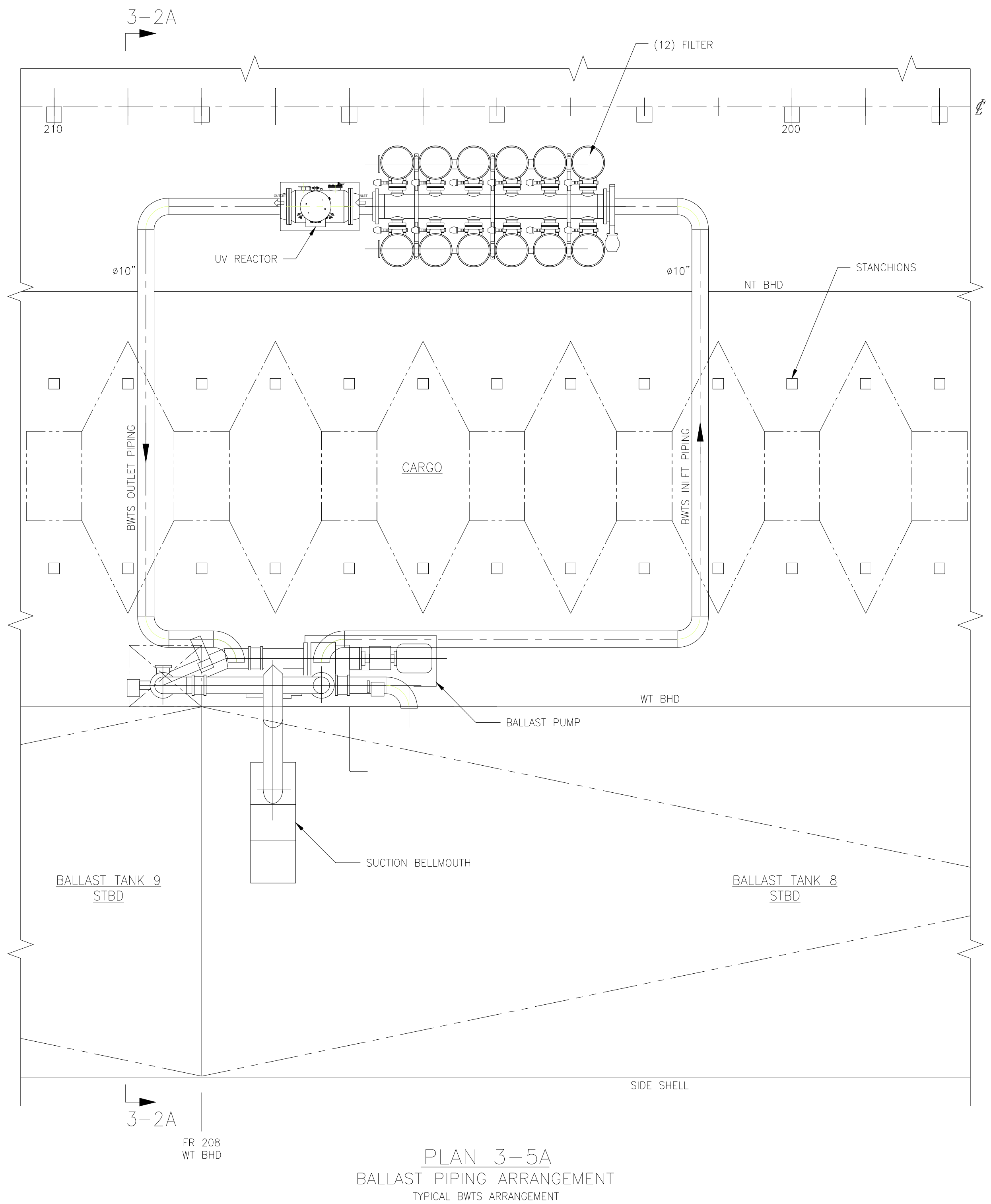


Figure A-1. Vessel One, BWT System 1 (filter/UV BWT System): piping diagram and general arrangement (2 of 3).



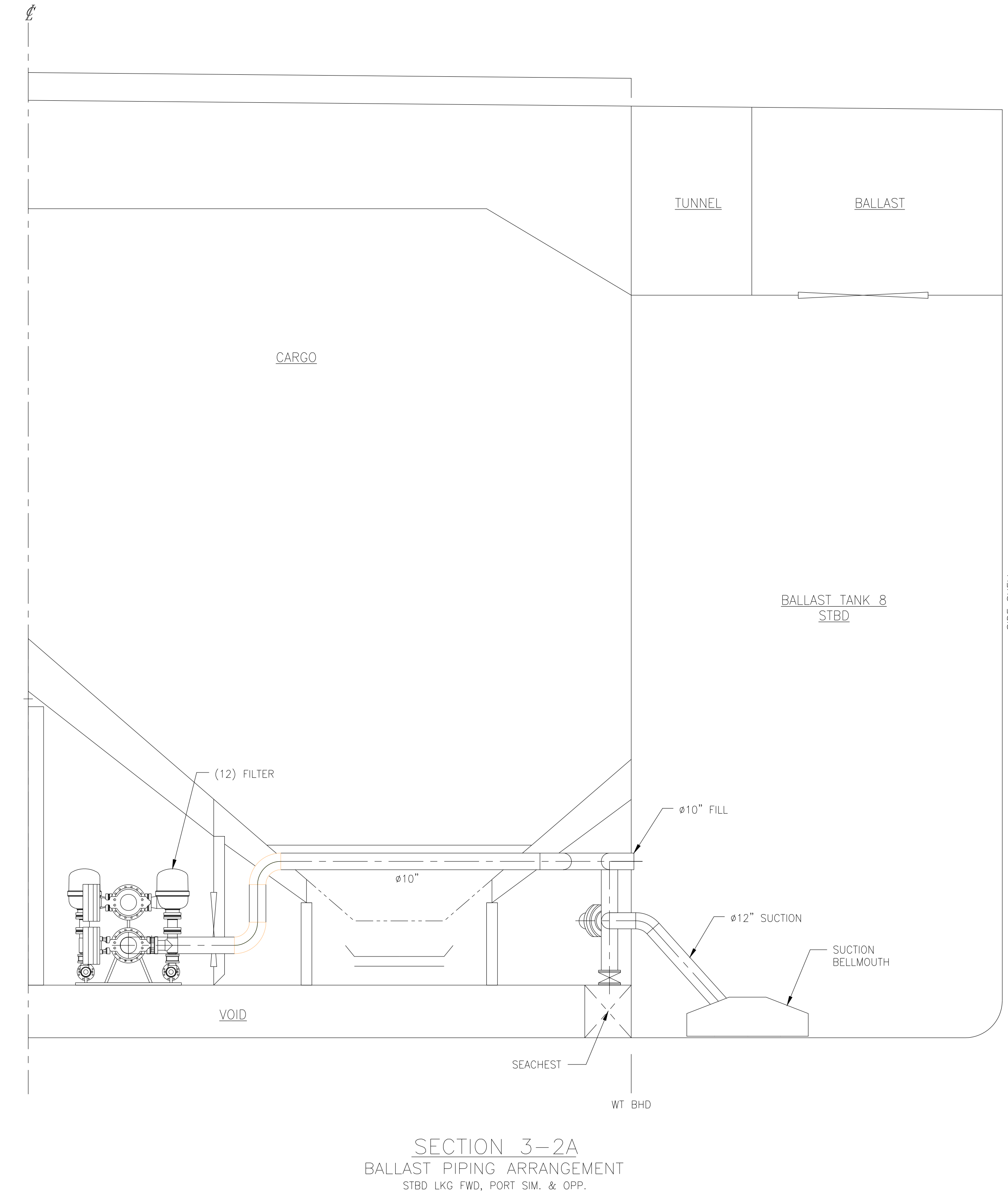


Figure A-1. Vessel One, BWT System 1 (filter/UV BWT System): piping diagram and general arrangement (3 of 3).

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A.2 Vessel One, BWT System 2

A.2.1 Vessel One, BWT System 2: Electrical Loads Analysis

The vessel does not have the electrical power capacity to operate the BWT system. New electrical diesel generators are added to power the BWT system. The BWT system requires an additional 1,386 kW; see Table A-4.

Table A-4. Vessel One, BWT System 2: electrical loads summary.

	#	power (kW)	total (kW)
Air Compressors	2	150	300
Ozone Generator	1	370	370
Chillers	2	252	504
Chiller Pumps	2	5	10
Ozone Injector Pumps	2	83	166
Ventilation	2	18	35
Lighting	1	1	1
		Total	**1,386**

A.2.2 Vessel One, BWT System 2: Deadweight Analysis

The light-ship weight of the vessel increases because of the addition of the BWT system, generator and electrical system installation, and ancillary system changes. The weight change decreases the cargo-carrying capacity of the vessel. Table A-5 provides the summary weight estimate.

Table A-5. Vessel One, BWT System 2: weight estimate summary.

		weight (lb)
Structure and piping		40,731
Ozone generation machinery		140,606
generators and electrical system		43,208
	Total (lb)	**224,545**
	Total(lt)	**100.2**

A.2.3 Vessel One, BWT System 2: Cost Estimate

The vessel will have to be modified for the installation of the BWT. Structural changes and existing system will have to be modified. The modification will require accesses to be cut and repaired. The summary cost is $7,731,190; see Table A-6.

A.2.4 Vessel One, BWT System 2: System Installation Drawings

The vessel structure and mechanical system will be modified for the BWT systems. The proposed structural and piping changes are shown in Figure A-2.

Table A-6. Vessel One, BWT System 2: cost estimate summary.

Preliminary Cost Estimate Summary: Shipboard Ozone BWT System									
SWBS No.	**Item Description**	**Labor Hours**	**Material & Services @ Cost ($)**	**Subcontracts @ Cost ($)**	**Labor Cost @ $70/Hr**	**Material & Services w/17% Mark-up ($)**	**Subcontracts w/8% Mark-up ($)**	**Item Total Costs**	**Percent of Total Cost**
000	Project Management & Admin	375	$249,141	$94,080	$26,248	$291,495	$--	$317,744	4.11%
100	Structure	6272	$98,070	$--	$439,037	$114,742	$--	$553,779	7.16%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	5490	$520,325	$--	$384,301	$608,780	$--	$993,082	12.85%
400	Electronics & IC Systems	954	$19,600	$--	$66,797	$22,932	$--	$89,729	1.16%
500	Auxiliary Systems	11517	$115,502	$2,240,000	$806,172	$135,138	$2,419,200	$3,360,509	43.47%
600	Outfitting	1434	$14,762	$--	$100,352	$17,271	$--	$117,623	1.52%
700	Mission Specific Equipment	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	108	$442,568	$--	$7,526	$517,805	$--	$525,331	6.79%
900	Shipyard Support Services	5264	$143,136	$53,312	$368,480	$167,469	$58,110	$594,059	7.68%
	Contingency @ 18% **Based on Concept Design Level**							**$1,179,334**	**15.25%**
	Totals for All Items	**31413**	**$1,603,104**	**$2,387,392**	**$2,198,914**	**$1,875,632**	**$2,477,310**	**$7,731,190**	**100%**

MATERIAL SCHEDULE

SERVICE	SIZE	PIPE	TAKEDOWN JOINTS			FITTINGS	VALVES		REMARKS
			MATERIAL	GASKETS	BOLTING		BODY	TRIM	
BALLAST WATER	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28	BUTTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS	

SYMBOLS LIST

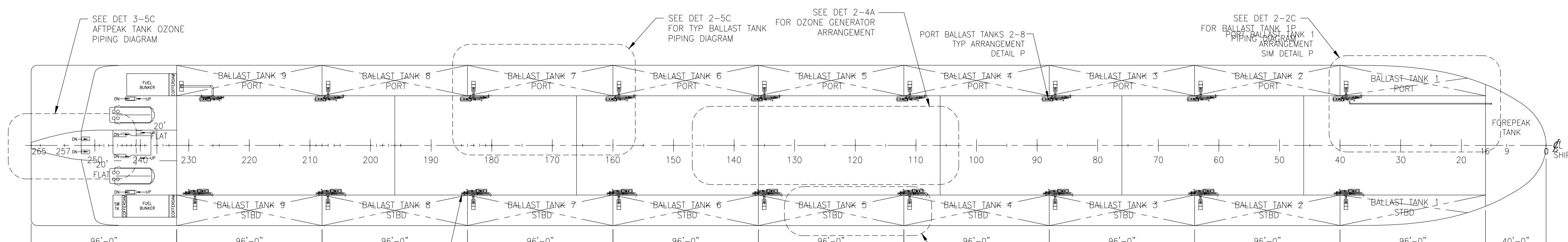
	NEW PIPE W/ FLOW DIRECTION
	EXISTING PIPE W/ FLOW DIRECTION
	BUTTERFLY VALVE REMOTELY OPERATED (ELEC THROTTLING) W/ CAPABILITY OF MANUAL OPERATION
	BUTTERFLY VALVE REMOTELY OPERATED (AIR OPEN OR CLOSE) W/ CAPABILITY OF MANUAL OPERATION
	BUTTERFLY VALVE
	GLOBE VALVE
	FLOW CONTROL VALVE
	BHD/DECK PENETRATION
	SWING CHECK VALVE
	PRESSURE GAUGE
	DRESSER COUPLING W/ ANCHOR BOLTS
	CROSSING PIPES CONNECTED
	CROSSING PIPES NOT CONNECTED
	SEACHEST
	SUCTION BELLMOUTH
	INJECTION SECTION W/ NOZZLE

MAJOR EQUIPMENT LIST

PART	QTY.	ITEM	MAKE	MODEL	CAPACITY	DRIVE/NOTES
C-1	2	AIR COMPRESSOR	ATLAS COPCO	GA160FF	928 CFM	200 HP
R-1 R-2	4	RECEIVER	OGSI	AST-1550/OST-1550	1550 GAL	–
G-1	2	OXYGEN GENERATOR	OGSI	OG-4000	4000 SCF/HR	50 WATTS 120 VAC, 60 HZ, 1Ø
G-2	1	OZONE GENERATOR	ITT WEDECO	PDO 2500	1875 LB/DAY	370 KW 480 VAC, 60 HZ, 3Ø
CH-1	2	CHILLER	FILTRINE	PCP-8000-860W	860,000 BTU/HR	252 KW 480 VAC, 60 HZ, 3Ø
F-1A F-1B	4	COALESCING FILTER	WILKERSON	M36-0C-000	950 SCFM	–
F-2	2	.01 MICRON FILTER	WALMEC	WNA SAM-075	75 SCFM	–
I-1	2	OZONE INJECTOR	–	–	–	–
N-1	19	INJECTOR SECTION W/ NOZZLE	–	–	–	–
G-2 PSU	1	POWER SUPPLY UNIT	ITT WEDECO	PDO 2500	–	480 VAC, 60 HZ, 3Ø
G-2 HVT	1	HIGH VOLTAGE TRANSFORMER	ITT WEDECO	PDO 2500	–	480 VAC, 60 HZ, 3Ø

PUMP LIST

PART	QTY.	SERVICE	TYPE	MODEL	CAPACITY	DRIVE
P-1	2	OZONE INJECTION SYSTEM	CENTRIFUGAL	GOULDS 3196 MTi (3X4-10)	690 GPM @350 FT	100HP, 460V, 3Ø
P-2	2	CONDENSER WATER PUMP	CENTRIFUGAL	GOULDS 2ST1H5B2	80 GPM @75 FT	3HP, 230V, 3Ø



KEY PLAN 1-4A
INTERMEDIATE TO LARGE CAPACITY 1000' LAKER
TANK ARRANGEMENT

Figure A-2. Vessel One, BWT System 2 (ozone BWT System): piping diagram and general arrangement (1 of 4).

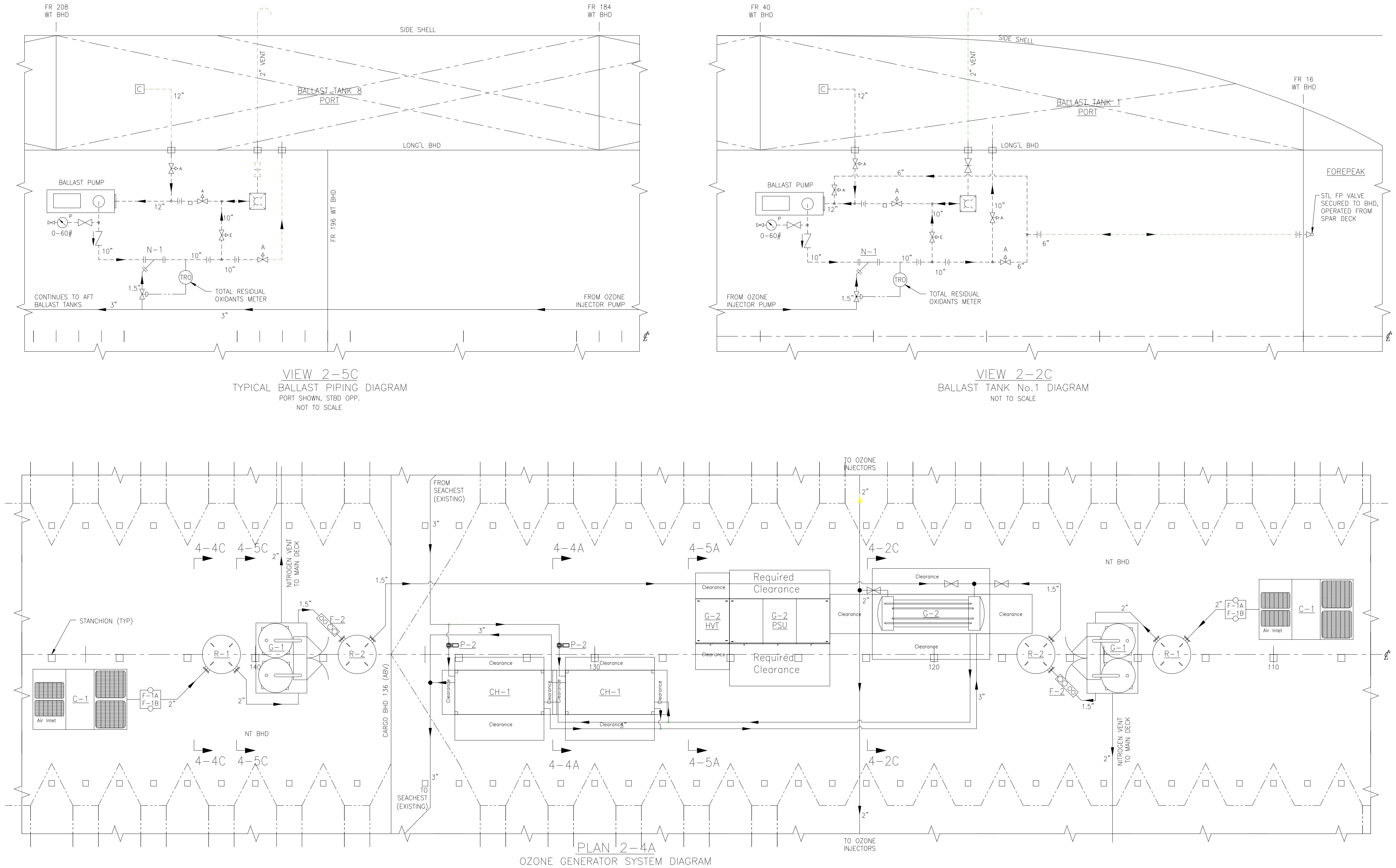


Figure A-2. Vessel One, BWT System 2 (ozone BWT System): piping diagram and general arrangement (2 of 4).

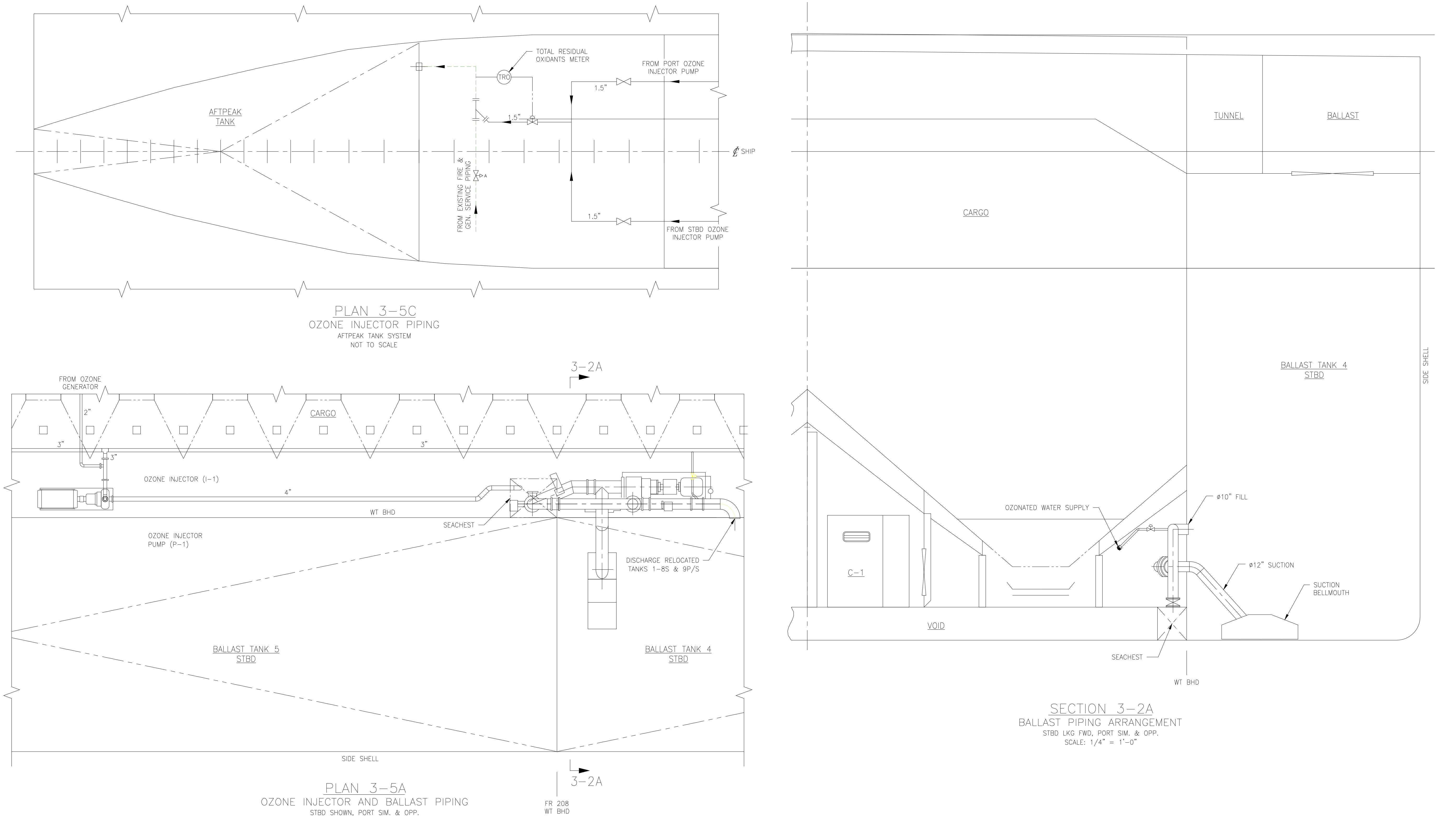


Figure A-2. Vessel One, BWT System 2 (ozone BWT System): piping diagram and general arrangement (3 of 4).

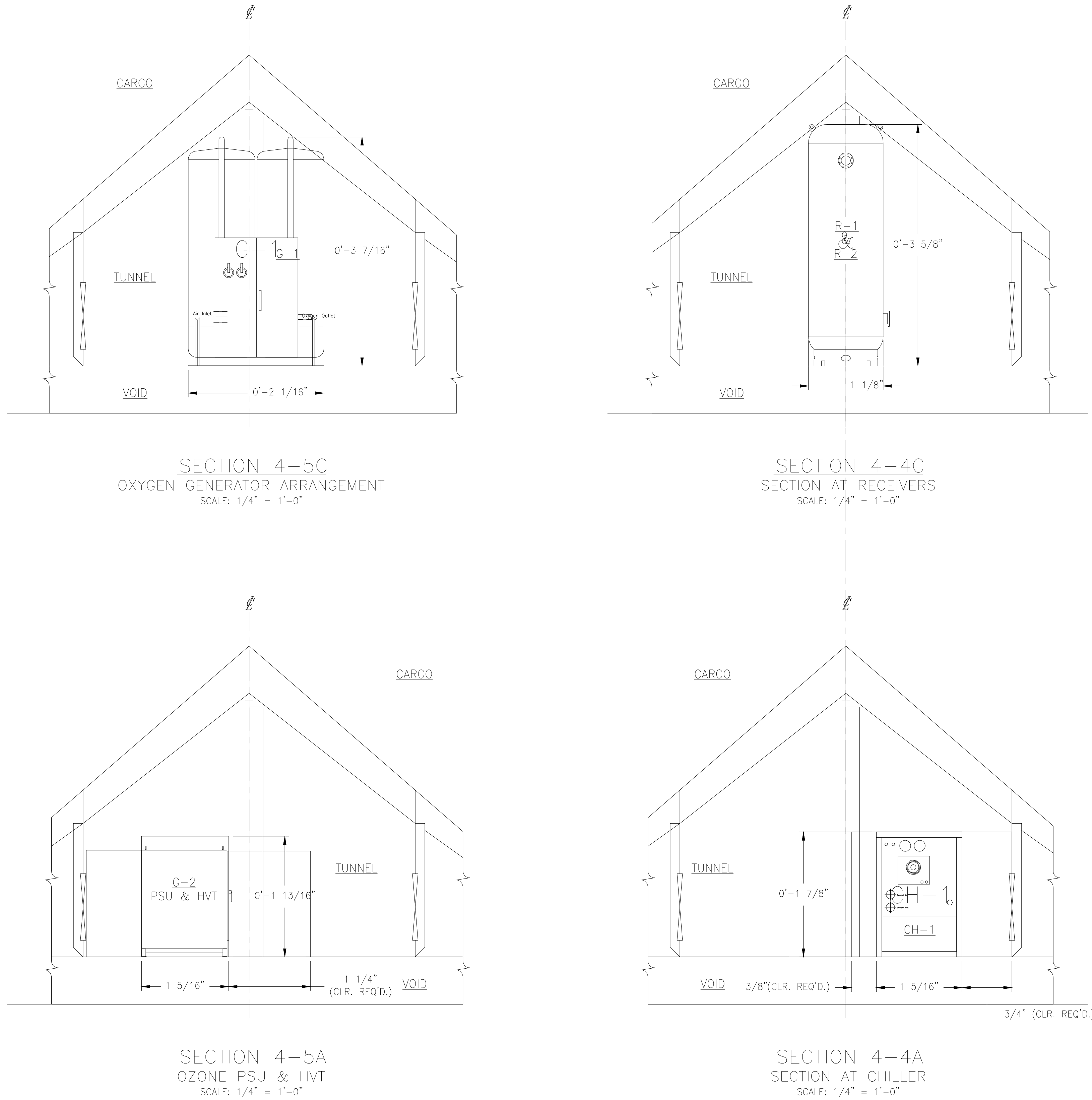


Figure A-2. Vessel One, BWT System 2 (ozone BWT System): piping diagram and general arrangement (4 of 4).

APPENDIX B VESSEL TWO (LARGE CAPACITY 1000' LAKER), BWT SYSTEMS: SUPPORTING DOCUMENTS

B.1 Vessel Two, BWT System 1

B.1.1 Vessel Two, BWT System 1: Electrical Loads Analysis

The addition of the BWT increases the electrical load on the vessel. The existing electrical power for the vessel is 1200 kW. The electrical power has to increase to 1,791 kW to accommodate the addition of the BWT. The change in electrical load provided in Table B-1.

B.1.2 Vessel Two, BWT System 1: Deadweight Analysis

The modification to the vessel for the addition of the BWT will change the light-ship weight. The changes result from the addition of the BWT, electrical power increase, ancillary system changes. The original light-ship displacement is 13,389 lt. The addition of the equipment increases the light-ship estimate to 13,556 lt. The resulting change decreases cargo carrying capacity. The weight estimate summary is provided in Table B-2, supporting Table B-3 through Table B-7.

B.1.3 Vessel Two, BWT System 1: Cost Estimate

The vessel will have to be modified for the installation of the BWT. Structural changes and existing system will have to be modified. The modification will require accesses to be cut and repaired. The summary cost is $11,618,542; see Table B-8.

B.1.4 Vessel Two, BWT System 1: System Installation Drawings

The vessel structure and mechanical system will be modified for the BWT systems. The general arrangement and structural changes are shown in Figure B-1. Piping modifications are shown in Figure B-2.

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Table B-1. Vessel Two, BWT System 1: electrical load analysis for the addition of the BWT.

EQUIPMENT LIST - FOR GENSET SIZING			Qty.		MECHANICAL INFO				ELECTRICAL LOADS INFO											Comments
							Mech Motor Rating				Demand Load (At Sea)		Demand Load (Docking)		Demand Load (Loading)		Demand Load (Unloading)		Power Source	
SWBS No.	Item	Description	Qty.	Units	Manufacturer	Model	Value	Unit	eKW	Voltage	Duty	eKW	Duty	eKW	Duty	eKW	Duty	eKW	(E/M/B)	
100	**Hull/Structural**																			
200	**Propulsion Plant**																			
220	Propulsion (E)	Existing propulsion systems	1	ea	N/A	N/A			97.7	450/3P	1.0	97.7	1.1	104.1	0.0	3.6	0.0	4.8	M	From B-0007 Electrical Load Analysis Winter Heat
300	**Electric Plant**																			
311	Ship service auxiliary(E)	Existing ship service	1	ea	N/A	N/A			40.6	120/1P	1.0	40.6	1.0	39.7	1.6	64.7	1.0	39.9	M	From B-0007 Electrical Load Analysis Winter Heat
311	Machine shop equipment(E)	Existing machine shop	1	ea	N/A	N/A			0.0	120/1P									M	From B-0007 Electrical Load Analysis Winter Heat
330	Lighting(E)	Existing lighting	1	ea	N/A	N/A			70.5	120/1P	1.0	70.5	1.0	70.5	1.0	70.5	1.0	70.5	M	From B-0007 Electrical Load Analysis Winter Heat
324	UV power panel(N)	BWT - UV power supply panel	8	ea	UV + Filter Vendor	5050VGSC1			N/A										B	Power accounted with UV reactor
324	BWT control panel(N)	BWT - system control panel	2	ea	UV + Filter Vendor	GCS-02			0.3	208/1P	1.0	0.3	0.0	0.0	1.0	0.3	1.0	0.3	B	From vendor proposal
324	Filter backwash pump panel(N)	Power panel for BWT backwash pump	2	ea	UV + Filter Vendor	N/A			N/A										B	Power accounted with filter pump
330	Lighting(N) new machinery space	Lighting for No. 7 ballast tank P/S	2	ea	N/A	N/A			12.9	208/1P	1.0	12.9	1.0	12.9	1.0	12.9	1.0	12.9	E	Guessed as each space = 1/3 power for engine room.
400	**Navigation/Communications**																			
400	Communication & navigation(E)	Existing coms & nav	1	kg	N/A	N/A			3.8	120/1P	1.0	3.8	0.9	3.5	0.1	0.5	0.1	0.5	M	From B-0007 Electrical Load Analysis Winter Heat
500	**Auxiliary Systems**																			
511	Electric heating system(E)	Existing heating	1	ea	N/A	N/A			111.0	208/1P	1.0	111.0	1.0	111.0	1.0	111.0	1.2	133.0	M	From B-0007 Electrical Load Analysis Winter Heat
512	Ventilation system(E)	Existing ventilation	1	ea	N/A	N/A			72.2	450/3P	1.0	72.2	1.0	72.2	1.0	72.2	1.0	72.2	M	From B-0007 Electrical Load Analysis Winter Heat
568	Deck equipment(E)	Existing deck equipment	1	ea	N/A	N/A			40.0	450/3P			1.0	40.0	0.4	16.0	0.4	16.0	M	From B-0007 Electrical Load Analysis Winter Heat
568	Bow thruster auxiliary(E)	Existing bow thruster	1	ea	N/A	N/A			0.8	450/3P	1.0	0.8	4.8	3.6	1.0	0.8	1.0	0.8	M	From B-0007 Electrical Load Analysis Winter Heat
573	Conveyor system auxiliary(E)	Existing conveyor system	1	ea	N/A	N/A			57.2	450/3P							1.0	57.2	M	From B-0007 Electrical Load Analysis Winter Heat
529	Filter unit	BWT filter assembly	2	ea	BWT vendor	SF90			N/A										B	
529	UV reactor	UV lamp reactor	8	ea	BWT vendor	201850	114.0		912.0	450/3P	0.5	456.0	0.0	0.0	1.0	912.0	1.0	912.0	B	From vendor proposal
529	Backwash pump	900 m^3/hr @5bar standby pump	2	ea	BWT vendor	TBD	384.6	kW	414.9	450/3P	1.0	414.9	0.0	0.0	1.0	414.9	1.0	414.9	B	From vendor proposal
512	New ventilation fan	No. 7 ballast tank P/S ventilation	2	ea	N/A	N/A	4.0	kW	5.1	450/1P	1.0	5.1	1.0	5.1	1.0	5.1	1.0	5.1	M	Estimate
511	Heaters(N) new machinery space	Heating for No. 7 balalst tank P/S	2	ea	N/A	N/A			2.5	208/1P	0.5	1.3	0.5	1.3	0.5	1.3	0.5	1.3	M	Estimate
600	**Outfit and Furnishings**																			
651	Galley(E)	Existing galley	1	kg	N/A	N/A			14.0	208/1P	1.0	14.0	1.0	14.0	1.0	14.0	1.0	14.0	M	From B-0007 Electrical Load Analysis Winter Heat
	Total Load											1301.0		477.8		1699.6		1755.2		
	Required Generator Rating	Rated power at 98% MCR					98%	MCR				1327.5		487.5		1734.3		1791.1		
	Available Generator Power		2		Marathon	742FDL5063	600.0	ekW				1200.0		1200.0		1200.0		1200.0		
	Remaining Power Required											**127.5**		**0.0**		**534.3**		**591.1**		

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Table B-2. Vessel Two, BWT System 1: dead weight estimate.

	VESSEL WEIGHT ESTIMATE						
SWBS No.	Description	Qty.	Total Wt. (lbs)	LCG **(+ aft)**	TCG **(+ stbd)**	VCG **(+ abl)**	Notes
	SUMMARY						
100	STRUCTURE CHANGES		94,707				See SWBS No. 100 for details
200	MACHINERY CHANGES		0				See SWBS No. 200 for details
300	ELECTRICAL CHANGES		24,861				See SWBS No. 300 for details
400	ELECTRONICS & IC CHANGES		0				See SWBS No. 400 for details
500	AUXILIARY SYSTEMS CHANGES		189,749				See SWBS No. 500 for details
600	OUTFIT CHANGES		3,987				See SWBS No. 600 for details
700	OPERATIONAL DEADWEIGHT		2,197,074				See SWBS No. 700 for details
000	PREVIOUS LIGHTSHIP		29,991,360				
	VESSEL WEIGHT - SUBTOTAL		32,501,737 (14,509.70LT)				
	Add Margin to Structure for Roll & Weld	3%	2,841				
	STRUCTURE	15%	14,206				
	ELECTRICAL	20%	4,972				
	AUXILIARY SYSTEMS	20%	37,950				
	OUTFIT	20%	797				
	VESSEL WEIGHT WITH MARGINS		**32,562,503 (14,536.83 LT)**				
	Minimum Loadline Draft				Keel Draft:	34.0 ft	Summer draft LL
	LOADLINE DISPLACEMENT		202,993,573 (90,622.13 LT)				Loading Guide Man.
	OPERATIONAL SHIP DISPLACEMENT		32,562,503 (14,536.83 LT)				100% Outfit Cond.
	AVAILABLE CARGO WEIGHT		**170,431,070 (76,085.30 LT)**			**Lost Capacity 0.2%**	**Prev. Cargo Weight (76,252.29 LT)**

Table B-3. Vessel Two, BWT System 1: structure weight estimate.

SWBS No.	Description	Qty.	Unit Wt. (lbs)	Total Wt. (lbs)	LCG (+ aft)	TCG (+ stbd)	VCG (+ abl)	Source C, E, V *		Notes
	New Machinery Space Changes									
100	New watertight door	2.00	300	600				E	P/S	
100	Add grating to primary level - Port							E	Port	
100	Stanchions - L4x3x1/4	320.00	6	1,837				E	Port	
100	Support beams - L4x3x1/4	700.00	6	4,018				E	Port	
100	Grating - 2 in	1200.00	3	3,600				E	Port	
100	Add grating to primary level - Stbd							E	Stbd	
100	Stanchions - L4x3x1/4	320.00	6	1,837				E	Stbd	
100	Support beams - L4x3x1/4	700.00	6	4,018				E	Stbd	
100	Grating - 2 in	1200.00	3	3,600				E	Stbd	
100	Add grating to secondary level - Port							E	Port	
100	Stanchions - L4x3x1/4	192.00	6	1,102				E	Port	
100	Support beams - L4x3x1/4	360.00	6	2,066				E	Port	
100	Grating - 2 in	450.00	3	1,350				E	Port	
100	Add grating to secondary level - Stbd							E	Stbd	
100	Stanchions - L4x3x1/4	192.00	6	1,102				E	Stbd	
100	Support beams - L4x3x1/4	360.00	6	2,066				E	Stbd	
100	Grating - 2 in	450.00	3	1,350				E	Stbd	
100	Foundations for new pipes	5.00	2240	11,200				E	P/S	
100	Foundations for BWT system	8.00	2240	17,920				E	P/S	
100	New main deck hatch	2.00	600	1,200				E	P/S	
								E	P/S	
	New supplementary generator - port							E	Port	
	Enclosure	8.00	2240	17,920				E	Port	
	New supplementary generator - Stbd							E	Stbd	
	Enclosure	8.00	2240	17,920				E	Stbd	
	STRUCTURE CHANGES - SUBTOTAL			94707 (42.28LT)						

Table B-4. Vessel Two, BWT System 1: electrical weight estimate.

SWBS No.	Description	Qty.	Unit Wt. (lbs)	Total Wt. (lbs)	LCG (+ aft)	TCG (+ stbd)	VCG (+ abl)	Source C, E, V *	Notes
	Overhead light fixtures	20.00	50	1,000				E	P/S
	Overhead emergency lighting	6.00	100	600				E	P/S
	Lighting power cables	1800.00	0	67				E	P/S
	Watertight bulkhead penetrations	4.00	50	200				E	P/S
	Ship service power receptacles	8.00	10	80				E	P/S
	Ship service power cables	720.00	0	27				E	P/S
	Ballast Water Treatment Components - Port								
	UV power panel	4.00	1323	5,291				V	Port
	Backwash pump power panel	1.00	441	441				E	Port
	System control panel	1.00	220	220				E	Port
	Control system wiring interconnect	500.00	0	19				E	Port
	Ballast Water Treatment Components - Stbd								
	UV power panel	4.00	1323	5,291				V	Stbd
	Backwash pump power panel	1.00	441	441				E	Stbd
	System control panel	1.00	220	220				E	Stbd
	System control panel	500.00	0	19				E	Stbd
	Supplementary generators								
	Power switchboard - Stbd	2.00	1000	2,000				E	
	Power switchboard - Port	2.00	1000	2,000				E	
	Cross connection - voltage regulator	2.00	100	200				E	
	Cross connection - synchroniser	2.00	100	200				E	
	Cross connection - wiring	120.00	55	6,545				C	P/S 3 Phase Delta 400A Wire
	ELECTRICAL CHANGES - SUBTOTAL			24861 (11.10LT)					

Table B-5. Vessel Two, BWT System 1: ship services weight estimate.

SWBS No.	Description	Qty.	Unit Wt. (lbs)	Total Wt. (lbs)	LCG (+ aft)	TCG (+ stbd)	VCG (+ abl)	Source C, E, V *	Notes
512	New compartment ventilation - Port							E	Port
512	Fan	1.00	600	600				E	Port
512	Ducting	75.00	10	750				E	Port
512	Watertight closure	1.00	200	200				E	Port
512	Fire damper	1.00	600	600				E	Port
512	New compartment ventilation - Stbd							E	Stbd
512	Fan	1.00	600	600				E	Stbd
512	Ducting	75.00	10	750				E	Stbd
512	Watertight closure	1.00	200	200				E	Stbd
512	Fire damper	1.00	600	600				E	Stbd
529	New bilge suction system								P/S
529	Piping - 2"	130.00	4	475				E	P/S
529	Valves	4.00	50	200				E	P/S
529	Suction bells	4.00	100	400				E	P/S
529	Ballast water treatment system components - Port							V	Port
529	Filter assembly	1.00	19401	19,401				V	Port
529	UV reactors	4.00	3307	13,228				V	Port
529	Backwash pump	1.00	3527	3,527				V	Port
529	Ballast water treatment system components - Stbd							V	Stbd
529	Filter assembly	1.00	19401	19,401				V	Stbd
529	UV reactors	4.00	3307	13,228				V	Stbd
529	Backwash pump	1.00	3527	3,527				V	Stbd
551	New pipes for ship service air	100.00	1	100				E	P/S
529	Remove main ballast header No 7 tank	-96.00	119	-11,386				C	P/S
529	Remove suction box No. 7 tank	-4.00	600	-2,400				E	P/S
529	New 30 in. pipe in No. 7 tank	262.00	119	31,073				C	P/S
529	New headers in No. 7 tank	976.00	31	29,936				C	P/S
529	New 16 in. drain pipe in No. 7 tank	139.33	63	8,722				C	P/S
529	New valves 30" diameter	6.00	3125	18,750				C	P/S - Based on Anvil Catalog
529	New 16 in. valves	12.00	1190	14,280				E	P/S
500	New Generator - Port								
500	Supplementary Generator	1.00	7615	7,615				V	Cat 3604C
500	CO2 System	4.00	200	800				E	Port
500	Fuel Day Tanks	1.00	2240	2,240				E	Port
500	Fuel transfer lines - 2"	120.00	4	438				C	Port
500	New Generator - Stbd								
500	Supplementary Generator	1.00	7615	7,615				V	Cat 3604C
500	CO2 System	4.00	200	800				E	Stbd
500	Fuel Day Tanks	1.00	2240	2,240				E	Stbd
500	Fuel transfer lines - 2"	120.00	4	438				C	Stbd
517	New electric space heaters	4.00	200	800				E	P/S
	AUXILIARY SYSTEMS CHANGES - SUBTOTAL			189749 (84.71 LT)					

Table B-6. Vessel Two, BWT System 1: outfitting weight estimate.

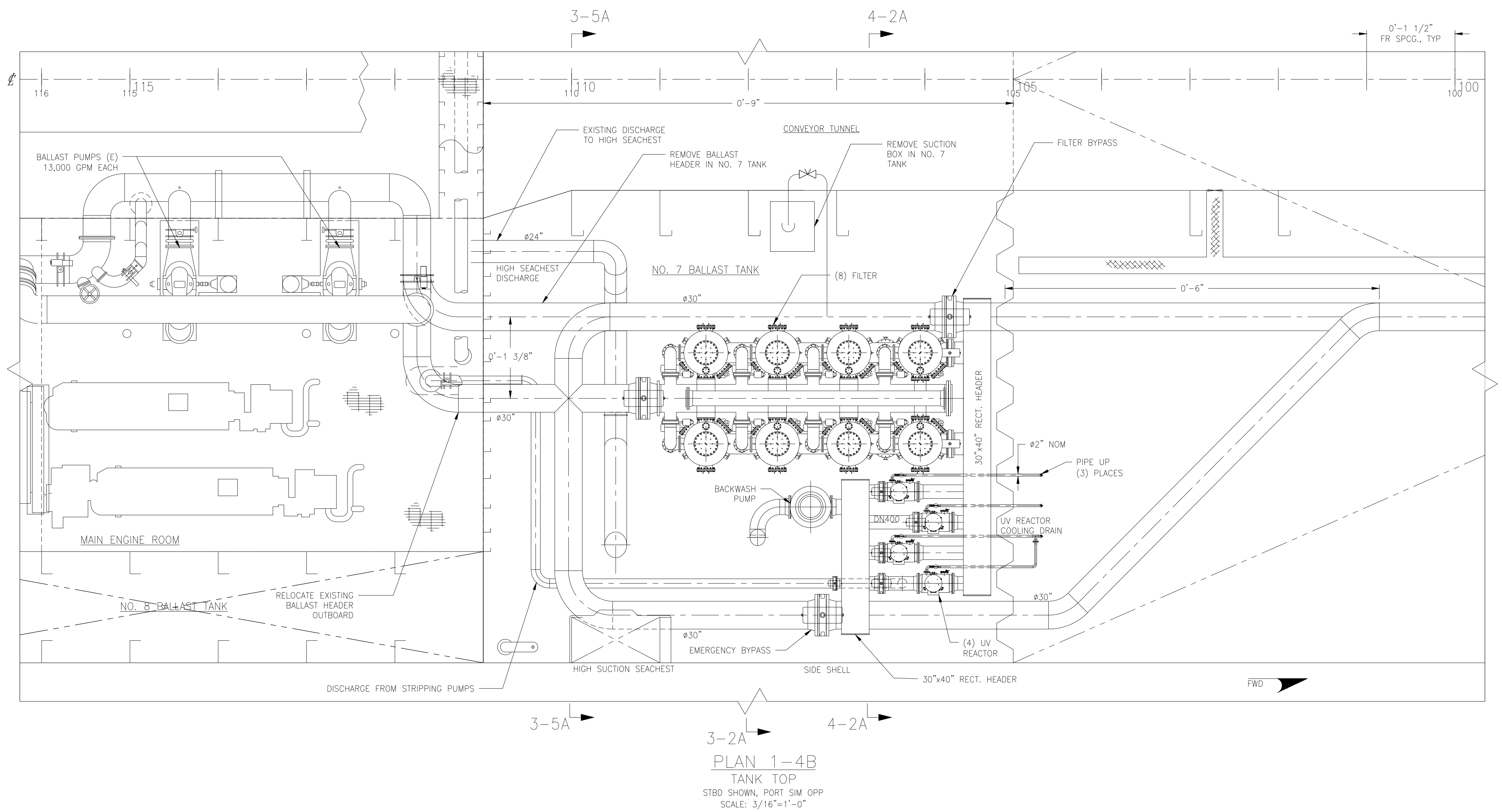
SWBS No.	Description	Qty.	Unit Wt. (lbs)	Total Wt. (lbs)	LCG (+ aft)	TCG (+ stbd)	VCG (+ abl)	Source C, E, V *	Notes
	Paint	0.024	94707	2,273					
	Typical assumption is 2.4% of hull weight for steel hull								
	or 4% of structure weight when hull is aluminum								
	Paint - Piping								
	2.4% of piping weight	0.024	69731	1,674					
	Fire extinguishers	2.00	10	20				E	P/S
	Smoke alarms	2.00	10	20				E	P/S
	OUTFIT CHANGES - SUBTOTAL			3987 (1.78 LT)					

Table B-7. Vessel Two, BWT System 1: operational deadweight estimate.

SWBS No.	Description	Qty.	Unit Wt. (lbs)	Total Wt. (lbs)	LCG (+ aft)	TCG (+ stbd)	VCG (+ abl)	Source C, E, V *	Notes
706	Provisions	25.00	300	7,500					
705	Crew	25.00	185	4,625					
707	Spares	10.00	2240	22,400					
708	Tools	5.00	2240						
710	Potable Water								
710	Port tank	8925.00	62	556,880				C	Loading Guidance Manual
710	Stbd tank	8925.00	62	556,880				C	Loading Guidance Manual
720	Fuel Oil								
720	Port tank	8925.00	54	480,692				C	Loading Guidance Manual
720	Stbd tank	8925.00	54	480,692				C	Loading Guidance Manual
730	Lube Oil								
730	Port tank	1075.00	58	61,902				C	Loading Guidance Manual
730	Stbd tank	0.00	58	0				C	Loading Guidance Manual
730	Sewage	408.70	62	25,501				C	Loading Guidance Manual
	OPERATIONAL DEADWEIGHT - SUBTOTAL			2197074 (980.84 LT)	0.00	0.00	0.000		

Table B-8. Vessel Two, BWT System 1: cost estimate summary.

Preliminary Cost Estimate Summary: Shipboard Filtration/UV BWT System									
SWBS No.	**Item Description**	**Labor Hours**	**Material & Services @ Cost ($)**	**Subcontracts @ Cost ($)**	**Labor Cost @ $70/Hr**	**Material & Services w/17% Mark-up ($)**	**Subcontracts w/8% Mark-up ($)**	**Item Total Costs**	**Percent of Total Cost**
000	Project Management & Admin	230	$392,952	$378,784	$16,088	$459,754	$409,087	$884,928	7.62%
100	Structure	5415	$143,405	$--	$379,064	$167,784	$--	$546,848	4.71%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	6576	$515,487	$--	$460,286	$603,119	$--	$1,063,406	9.15%
400	Electronics & IC Systems	246	$3,248	$--	$17,248	$3,800	$--	$21,048	0.18%
500	Auxiliary Systems	6543	$241,387	$4,767,140	$458,013	$282,423	$5,148,511	$5,888,947	50.69%
600	Outfitting	703	$13,854	$--	$49,235	$16,210	$--	$65,445	0.56%
700	Mission Specific Equipment	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	108	$32,648	$560,000	$7,526	$38,198	$604,800	$650,525	5.60%
900	Shipyard Support Services	3562	$296,486	$119,328	$249,312	$346,889	$128,874	$725,075	6.24%
	Contingency @ 18%							**$1,772,320**	**15.25%**
	Based on Concept Design Level								
	TOTALS FOR ALL ITEMS	**23382**	**$1,639,468**	**$5,825,252**	**$1,636,772**	**$1,918,177**	**$6,291,272**	**$11,618,542**	**100%**



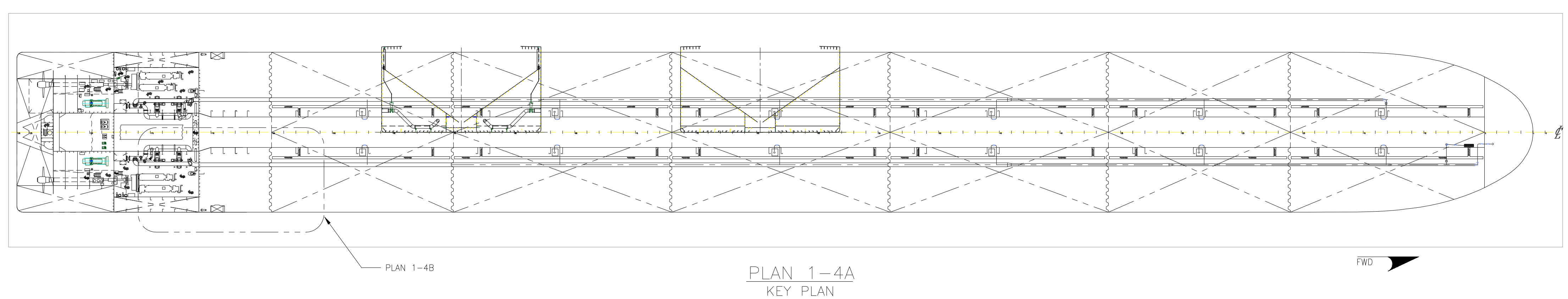


Figure B-1. Vessel Two, BWT System 1 (filter/UV BWT System): general and piping arrangement (1 of 4).

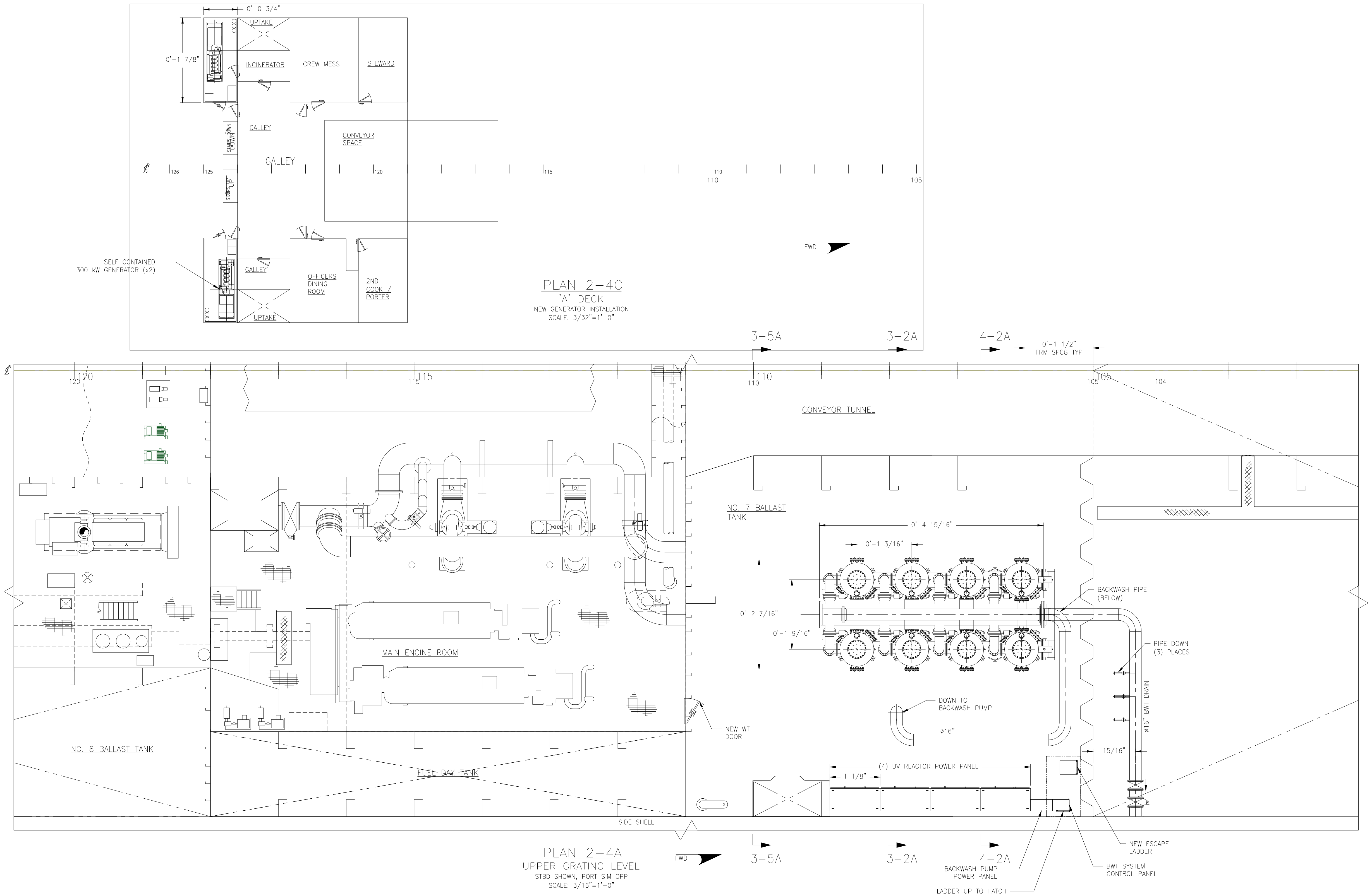
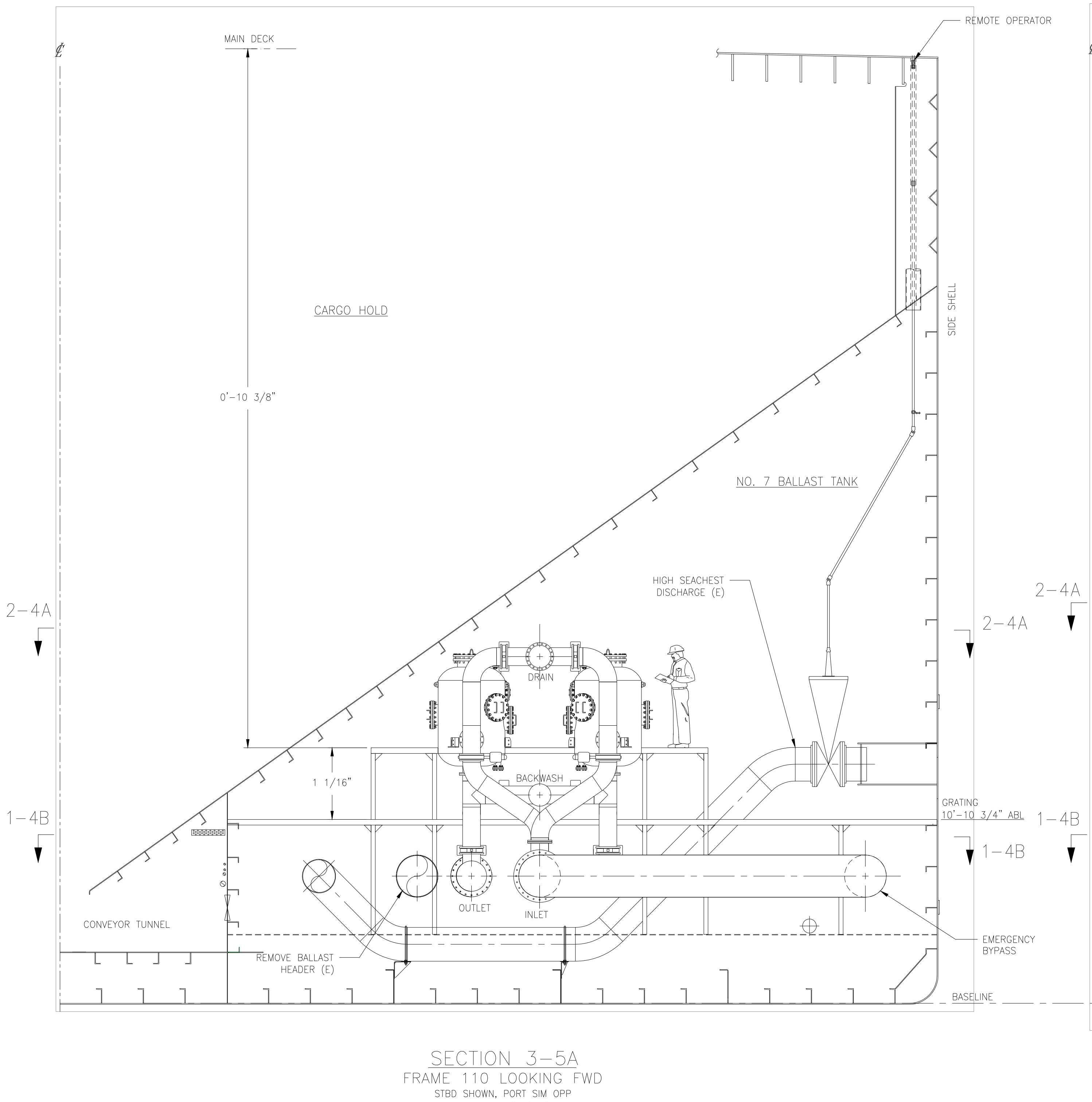


Figure B-1. Vessel Two, BWT System 1 (filter/UV BWT System): general and piping arrangement (2 of 4).



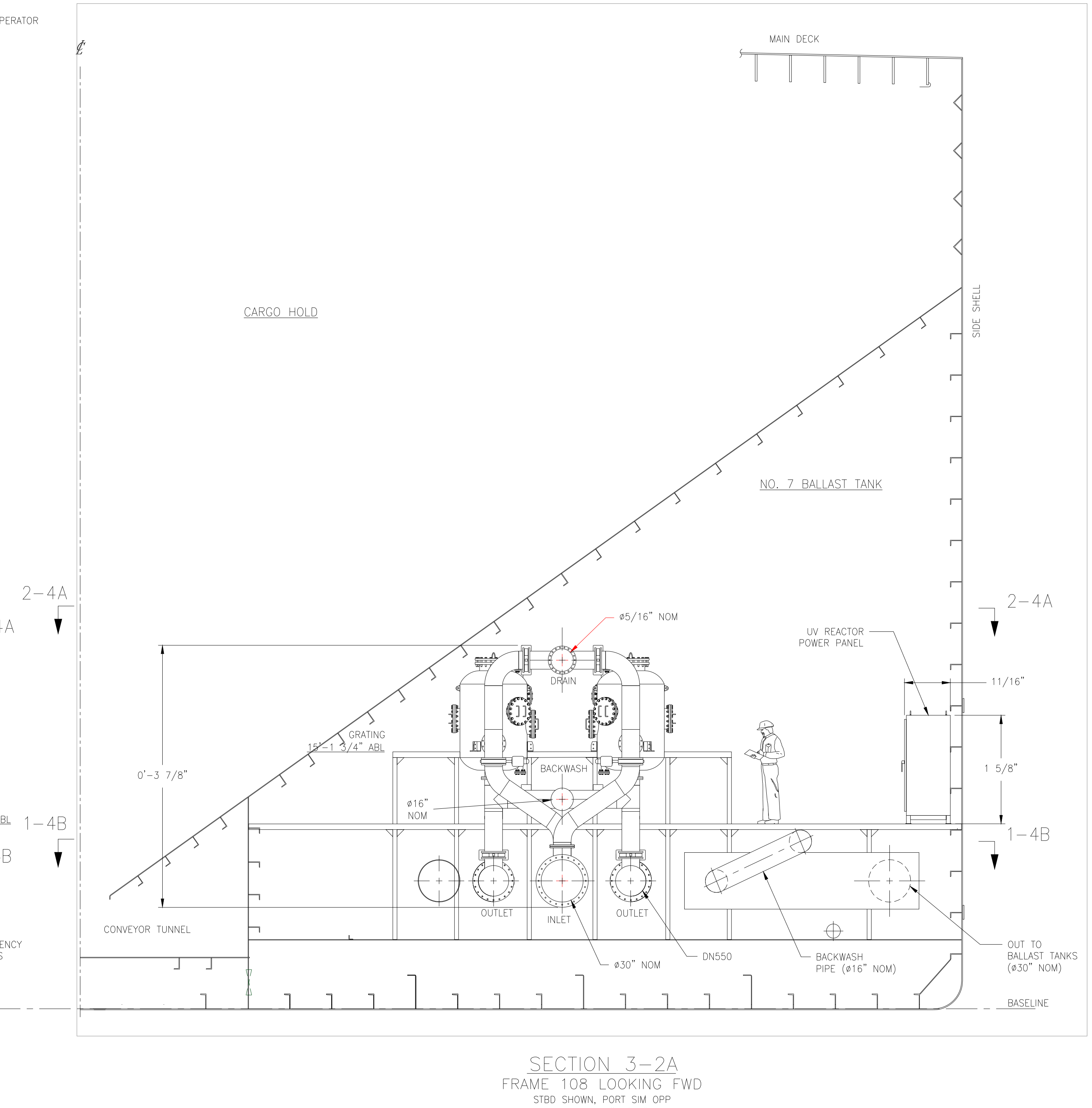


Figure B-1. Vessel Two, BWT System 1 (filter/UV BWT System): general and piping arrangement (3 of 4).

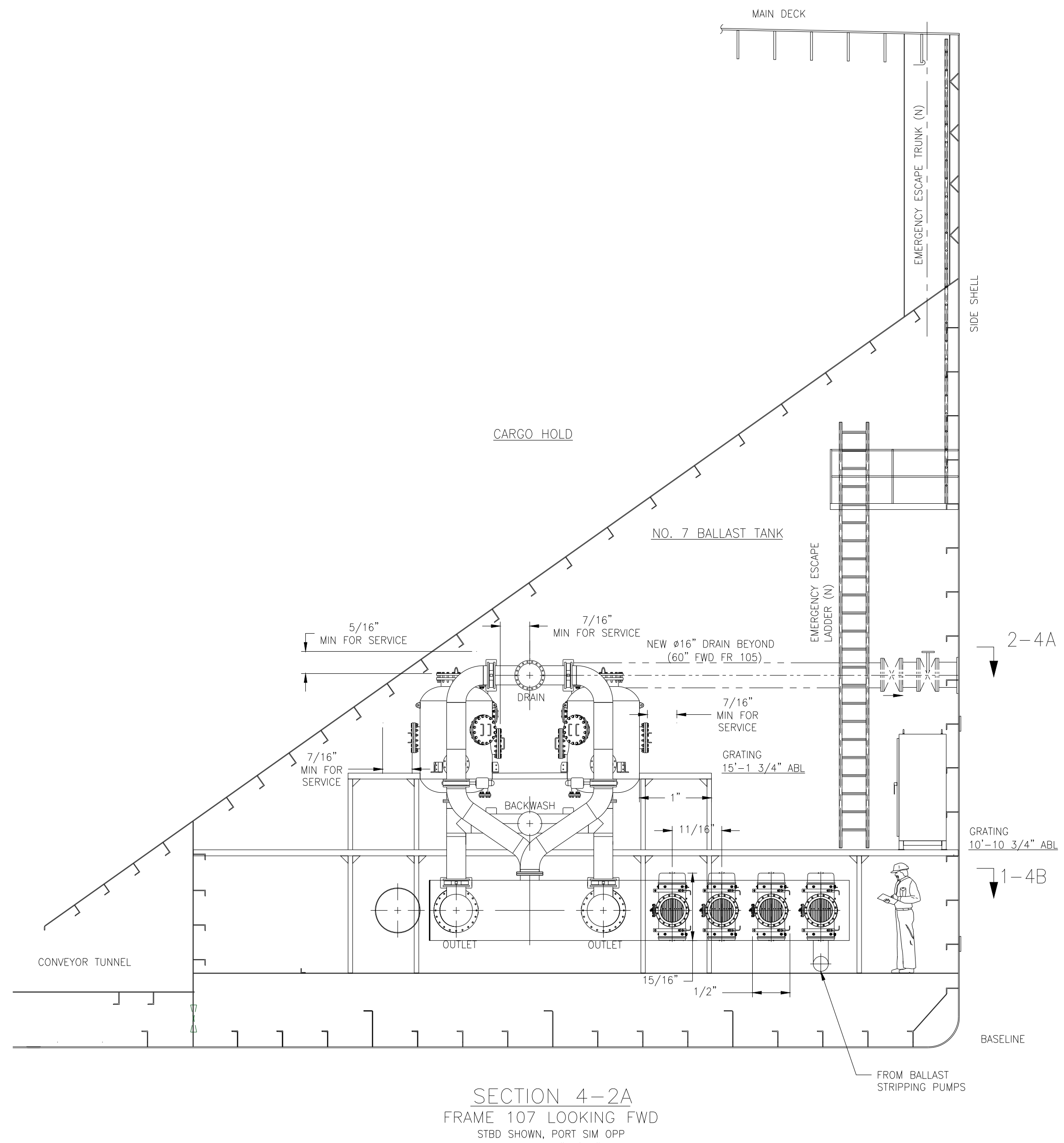


Figure B 1. Vessel Two, BWT System 1 (filter/UV BWT System): general and piping arrangement (4 of 4).

MATERIAL SCHEDULE

SERVICE	SIZE	PIPE	TAKEDOWN JOINTS			FITTINGS	VALVES		REMARKS
			MATERIAL	GASKETS	BOLTING		BODY	TRIM	
BALLAST WATER	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28	BUTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS	

SYMBOLS LIST

	PIPE W/ FLOW DIRECTION
	EXISTING PIPE W/ FLOW DIRECTION
	PNEUMATIC CONTROLLED DOUBLE ACTING BUTTERFLY VALVE (OPEN/CLOSE)
	REMOTE ACTUATED DOUBLE ACTING BUTTERFLY VALVE (OPEN/CLOSE)
	BUTTERFLY VALVE
FILTER_MODEL	FILTER SYSTEM
	UV CHAMBER
	SWING CHECK VALVE
DPS	DELTA P SENSOR
	CENTRIFUGAL PUMP
	FLANGED CONNECTION
	REDUCER
	CROSSING PIPES CONNECTED
	CROSSING PIPES NOT CONNECTED
FM	FLOW METER
	SEACHEST
	INCLUDED WITH BALLAST WATER TREATMENT SYSTEM
	OVERBOARD DISCHARGE
	GATE VALVE

MAJOR EQUIPMENT LIST

QTY.	ITEM	MAKE	MODEL	CAPACITY	DRIVE/NOTES
6	BUTTERFLY VALVE	–	ø30"	–	PNEUMATIC
8	SWING CHECK VALVE	–	ø2"	–	–
2	SWING CHECK VALVE	–	ø16"	–	–
2	SWING CHECK VALVE	–	ø30"	–	–
2	GATE VALVE	–	ø16"	–	PNEUMATIC
4	BUTTERFLY VALVE	–	ø1/2"	–	PNEUMATIC

NOTE: QUANTITIES LISTED ARE FOR BOTH SIDES OF SHIP.

PUMP LIST

QTY.	SERVICE	TYPE	MODEL	CAPACITY	DRIVE
2	STRIPPING PUMP (EXISTING)	CENTRIFUGAL	–	3,000 GPM	–
4	MAIN BALLAST PUMP (EXISTING)	CENTRIFUGAL	ALLIS CHALMERS, MODEL WSDV	13,000 GPM	200 HP ELECTRIC MOTOR
2	BACKWASH PUMP	CENTRIFUGAL	–	3,963 GPM AT 5 BAR	250 HP ELECTRIC MOTOR

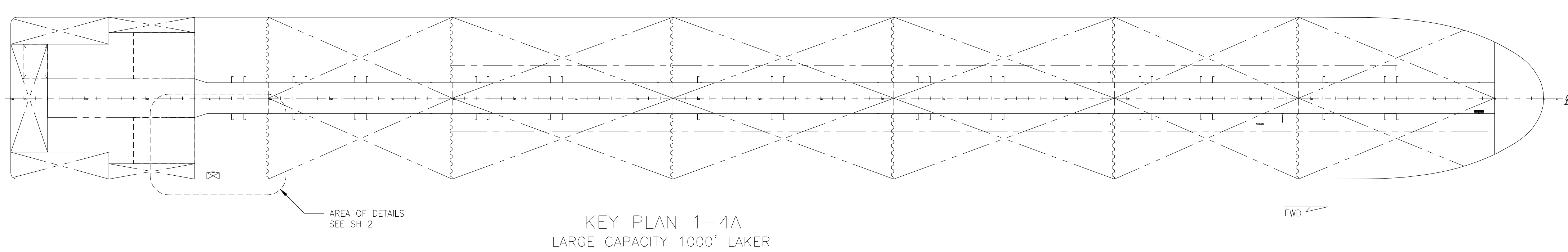


Figure B-2. Vessel Two, BWT System 1 (filter/UV BWT System): piping diagram (1 of 2).

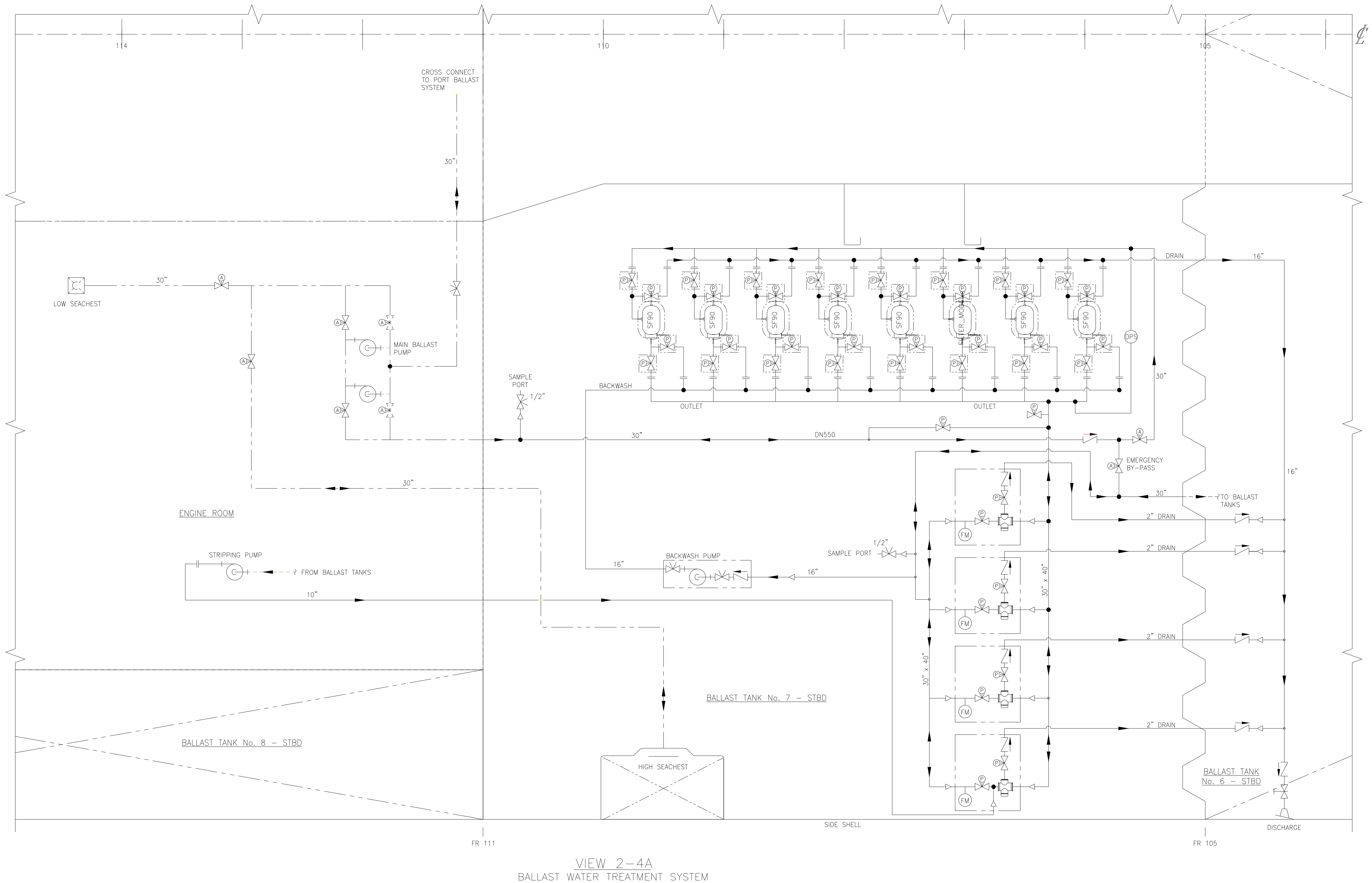


Figure B-2. Vessel Two, BWT System 1 (filter/UV BWT System): piping diagram (2 of 2).

B.2 Vessel Two, BWT System 2

B.2.1 Vessel Two, BWT System 2: Ventilation Calculations

The ozone BWT system is located in a single space. The system has a large air requirement to operate; see Table B-9.

Table B-9. Vessel Two, BWT System 2: ventilation calculations.

Summary

This spreadsheet performs calculations to determine required ventilation for new BWT machinery space.

Air Requirements for Machinery

Item	*Formula*	*Value*	*Units*
Air compressor 1 inlet	Qc1 =	7,891.16	*cfm*
Air compressor 2 inlet	Qc2 =	7,891.16	*cfm*
Supplementary generator air cooling requirement	Qg1 =	17,551.00	*cfm*
Total air requirement	Qt1 = Qc1 + Qc2 + Qg1	33,333.32	*cfm*
Extra air provided for adequate ventilation	Qt2 = 2 * Qt1	66,666.63	*cfm*
Total ventilation required	**Qt = Qt1 + Qt2**	**99,999.95**	***cfm***
Ventilation per fan	**Qf = Qt / 2**	**33,333.32**	***cfm***

Selected Fan

Make	*Model*	*Dimensions*		*Units*
Hartzell	A48-486DA-ST_4	Size	48.00	*in*
		Static Pressure	0.75	*in*
		Flow Rate	42,856.00	*cfm*
		Motor RPM	1,140.00	*rpm*
		Motor Power	14.79	*Hp*

B.2.2 Vessel Two, BWT System 2: Electrical Loads Analysis

The addition of the BWT increases the electrical load on the vessel. The existing electrical power for the vessel is 1,200 kW. The electrical power increased to 1,477.1 kW to accommodate the addition of the BWT. The change in electrical load is provided in Table B-10.

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Table B-10. Vessel Two, BWT System 2: electrical load analysis for the addition of the BWT.

EQUIPMENT LIST - FOR GENSET SIZING

			Qty.		MECHANICAL INFO				ELECTRICAL LOADS INFO											Comments
SWBS							Mech Motor Rating				Demand Load (At Sea)		Demand Load (Docking)		Demand Load (Loading)		Demand Load (Unloading)		Power Source	
No.	Item	Description	Qty.	Units	Manufacturer	Model	Value	Unit	eKW	Voltage	Duty	eKW	Duty	eKW	Duty	eKW	Duty	eKW	(E/M/B)	
100	**Hull/Structural**																			
200	**Propulsion Plant**																			
220	Propulsion (E)	Existing propulsion systems	1	ea	N/A	N/A			97.7	450/3P	1.0	97.7	1.1	104.1	0.0	3.6	0.0	4.8	M	From B-0007 Electrical Load Analysis Winter Heat
300	**Electric Plant**																			
311	Ship service auxiliary(E)	Existing ship service	1	ea	N/A	N/A			40.6	120/1P	1.0	40.6	1.0	39.7	1.6	64.7	1.0	39.9	M	From B-0007 Electrical Load Analysis Winter Heat
311	Machine shop equipment(E)	Existing machine shop	1	ea	N/A	N/A			0.0	120/1P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	M	From B-0007 Electrical Load Analysis Winter Heat
330	Lighting(E)	Existing lighting	1	ea	N/A	N/A			70.5	120/1P	1.0	70.5	1.0	70.5	1.0	70.5	1.0	70.5	M	From B-0007 Electrical Load Analysis Winter Heat
324	Power panel for BWT (N)	Power for ozone generator	1	ea	Ozone Vendor	-			0	450/3P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	B	Power accounted with UV reactor
324	Transformer for BWT (N)	High voltage trans for ozone generator.	1	ea	Ozone Vendor	-			0	450/3P	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	B	From vendor proposal
330	Lighting(N) new machinery space	Lighting for No. 7 ballast tank P/S	1	ea	N/A	N/A			6.4	120/1P	1.0	6.4	1.0	6.4	1.0	6.4	1.0	6.4	E	Guessed as each space = 1/3 power for engine room.
400	**Navigation/Communications**																			
400	Communication & navigation(E)	Existing coms & nav	1	kg	N/A	N/A			3.8	120/1P	1.0	3.8	0.9	3.5	0.1	0.5	0.1	0.5	M	From B-0007 Electrical Load Analysis Winter Heat
500	**Auxiliary Systems**																			
511	Electric heating system(E)	Existing heating	1	ea	N/A	N/A			111.0	208/1P	1.0	111.0	1.0	111.0	1.0	111.0	1.2	133.0	M	From B-0007 Electrical Load Analysis Winter Heat
512	Ventilation system(E)	Existing ventilation	1	ea	N/A	N/A			72.2	450/3P	1.0	72.2	1.0	72.2	1.0	72.2	1.0	72.2	M	From B-0007 Electrical Load Analysis Winter Heat
568	Deck equipment(E)	Existing deck equipment	1	ea	N/A	N/A			40.0	450/3P	0.0	0.0	1.0	40.0	0.4	16.0	0.4	16.0	M	From B-0007 Electrical Load Analysis Winter Heat
568	Bow thruster auxiliary(E)	Existing bow thruster	1	ea	N/A	N/A			0.8	450/3P	1.0	0.8	4.8	3.6	1.0	0.8	1.0	0.8	M	From B-0007 Electrical Load Analysis Winter Heat
573	Conveyor system auxiliary(E)	Existing conveyor system	1	ea	N/A	N/A			57.2	450/3P	0.0	0.0	0.0	0.0	0.0	0.0	1.0	57.2	M	From B-0007 Electrical Load Analysis Winter Heat
529	Air compressors (N)	Compressors for ozone system	2	ea	Ozone Vendor	GA160	155.0	kW	344.5	450/3P	1.0	344.5	0.0	0.0	0.0	0.0	1.0	344.5	B	From vendor proposal
529	Air receivers (N)	Receivers for compressed air	2	ea	Ozone Vendor	AST-1550/OST-1550	0.0	kW	0.0		1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	B	From vendor proposal
529	Oxygen generators (N)	Oxygen generator from comp. air	2	ea	Ozone Vendor	OG-4000	0.060	kW	0.1	120/1P	1.0	0.1	0.0	0.0	0.0	0.0	1.0	0.1	B	From vendor proposal
529	Oxygen receivers (N)	Oxygen receivers	2	ea	Ozone Vendor	AST-1550/OST-1550	0.0	kW	0.0		1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	B	From vendor proposal
529	Ozone generator (N)	Ozone generator	1	ea	Ozone Vendor	PDO 2500	370.0	kW	370.0	480/3P	1.0	370.0	0.0	0.0	0.0	0.0	1.0	370.0	B	From vendor proposal
529	Chiller units (N)	Chillers for ozone generator	2	ea	Ozone Vendor	POC-8000-860	80.5	kW	182.8	230/3P	1.0	182.8	0.0	0.0	0.0	0.0	1.0	182.8	B	From vendor proposal
529	Condenser pumps (N)	Condenser pumps for chillers	2	ea	Ozone Vendor	2ST	3.0	HP	5.7	230/3P	1.0	5.7	0.0	0.0	0.0	0.0	1.0	5.7	B	From vendor proposal
529	Ozone injector pumps (N)	Ozone injection into main balalst line	2	ea	Ozone Vendor	3410 M 6x8-11	50.0	HP	86.1	230/3P	1.0	86.1	0.0	0.0	0.0	0.0	1.0	86.1	B	From vendor proposal
512	Ventilation fan (N)	No. 7 ballast tank Stbd ventilation	3	ea	Hartzell	A48-486DA-ST_4	14.8	HP	39.9	450/1P	1.0	39.9	0.3	13.3	0.3	12.0	1.0	39.9	M	From fan vendor spec
511	Heaters(N) new machinery space	Heating for No. 7 balalst tank P/S	2	ea	N/A	N/A			2.5	208/1P	0.5	1.3	0.5	1.3	0.5	1.3	0.5	1.3	M	Estimate
600	**Outfit and Furnishings**																			
651	Galley(E)	Existing galley	1	kg	N/A	N/A			14.0	208/1P	1.0	14.0	1.0	14.0	1.0	14.0	1.0	14.0	M	From B-0007 Electrical Load Analysis Winter Heat
	Total Load											1447.5		479.6		372.9		1445.8		
	Required Generator Rating	Rated power at 98% MCR					98%	MCR				1477.1		489.4		380.5		1475.3		
	Available Generator Power		2		Marathon	742FDL5063	600.0	ekW				1200.0		1200.0		1200.0		1200.0		
	Remaining Power Required											**277.1**		**0.0**		**0.0**		**275.3**		

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B.2.3 Vessel Two, BWT System 2: Cost Estimate

The vessel will have to be modified for the installation of the BWT. Structural changes and existing system will have to be modified. The modification will require accesses to be cut and repaired. The summary cost is $6,291,681; see Table B-11.

Table B-11. Vessel Two, BWT System 2: cost estimate summary.

Preliminary Cost Estimate Summary: Shipboard Ozone BWT System										
SWBS No.	Item Description	Labor Hours	Material & Services @ Cost ($)	Subcontracts @ Cost ($)	Labor Cost @ $70/Hr	Material & Services w/17% Mark-up ($)	Subcontracts w/8% Mark-up ($)	Item Total Costs	Percent of Total Cost
000	Project Management & Admin	254	$344,086	$--	$17,781	$402,581	$--	$420,362	6.68%
100	Structure	8149	$112,421	$--	$570,422	$131,532	$--	$701,954	11.16%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	6204	$291,364	$--	$434,305	$340,895	$--	$775,200	12.32%
400	Electronics & IC Systems	193	$2,442	$--	$13,485	$2,857	$--	$16,341	0.26%
500	Auxiliary Systems	5183	$68,320	$1,962,940	$362,835	$79,934	$2,119,975	$2,562,745	40.73%
600	Outfitting	703	$13,854	$--	$49,235	$16,210	$--	$65,445	1.04%
700	Mission Specific Equipment	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	108	$32,648	$352,800	$7,526	$38,198	$381,024	$426,749	6.78%
900	Shipyard Support Services	3760	$37,542	$51,878	$263,184	$43,925	$56,029	$363,137	5.77%
	Contingency @ 18% **Based on Concept Design Level**							**$959,748**	**15.25%**
	Totals For All Items	**24554**	**$902,677**	**$2,367,618**	**$1,718,773**	**$1,056,132**	**$2,557,028**	**$6,291,681**	**100%**

B.2.4 Vessel Two, BWT System 2: System Installation Drawings

The vessel structure and mechanical system will be modified for the BWT systems. The general arrangement and structural changes are shown in Figure B-3. Piping modifications are shown in Figure B-4.

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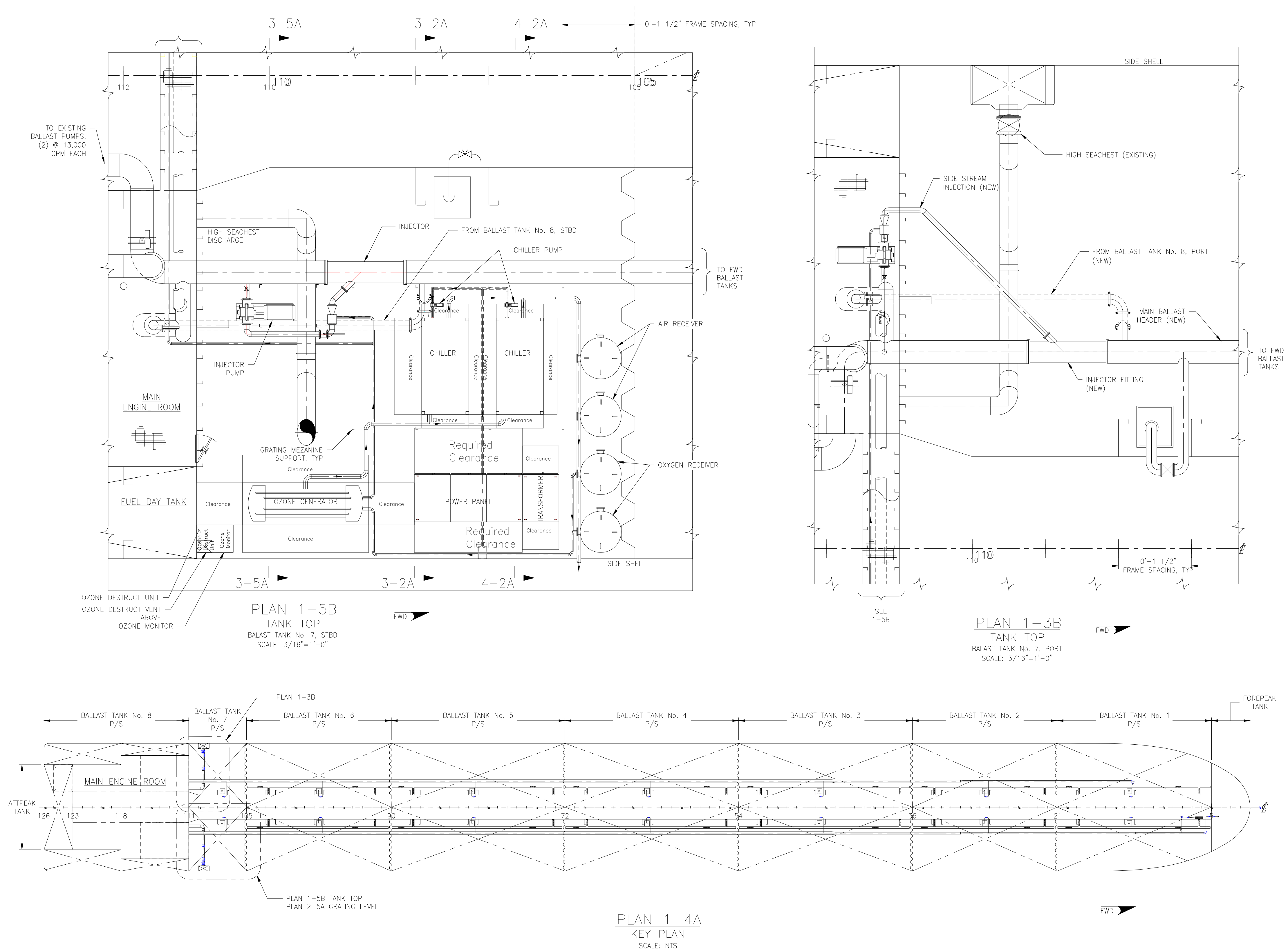
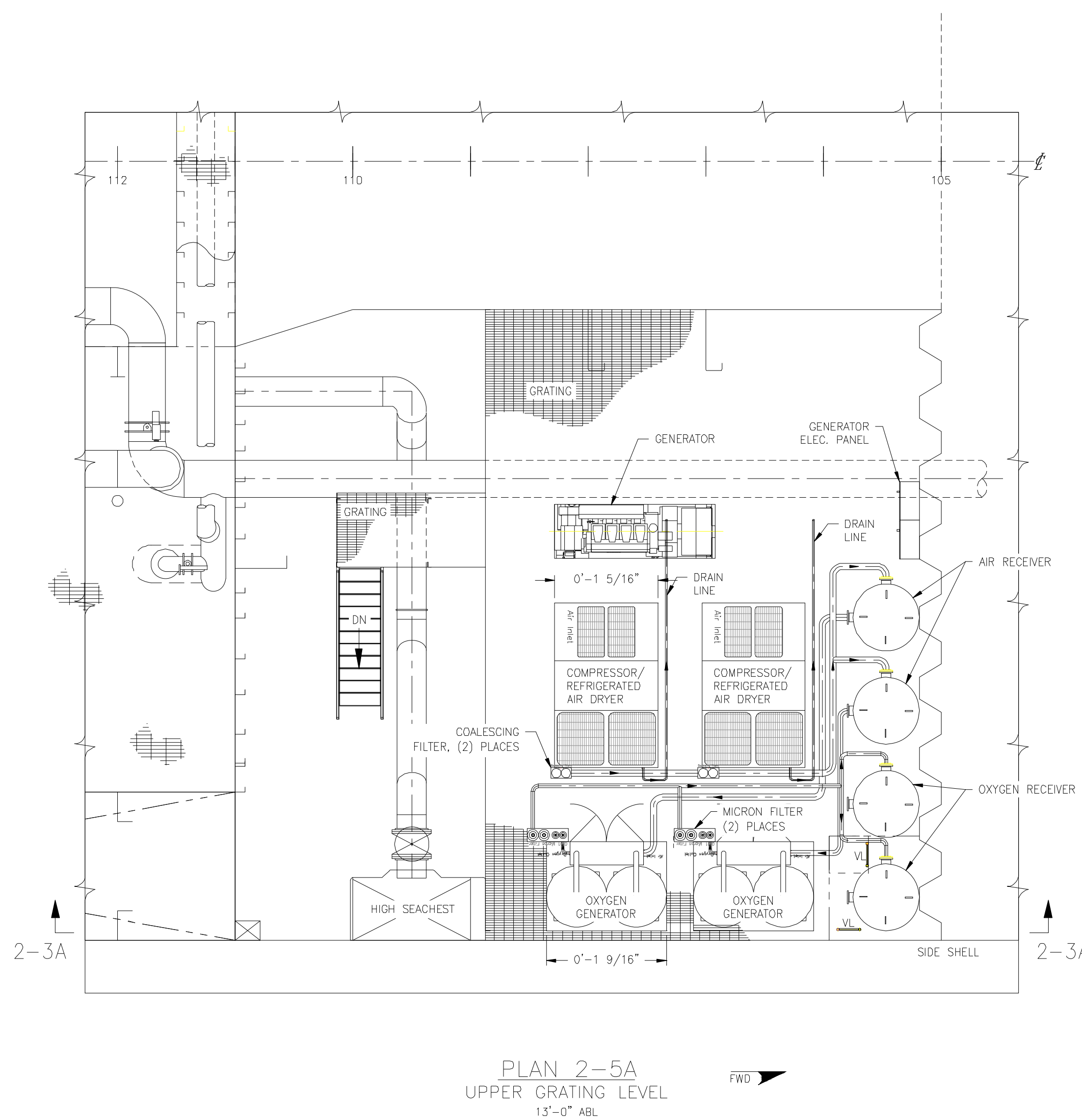


Figure B-3. Vessel Two, BWT System 2 (ozone BWT System): general arrangement and piping installation (1 of 4).



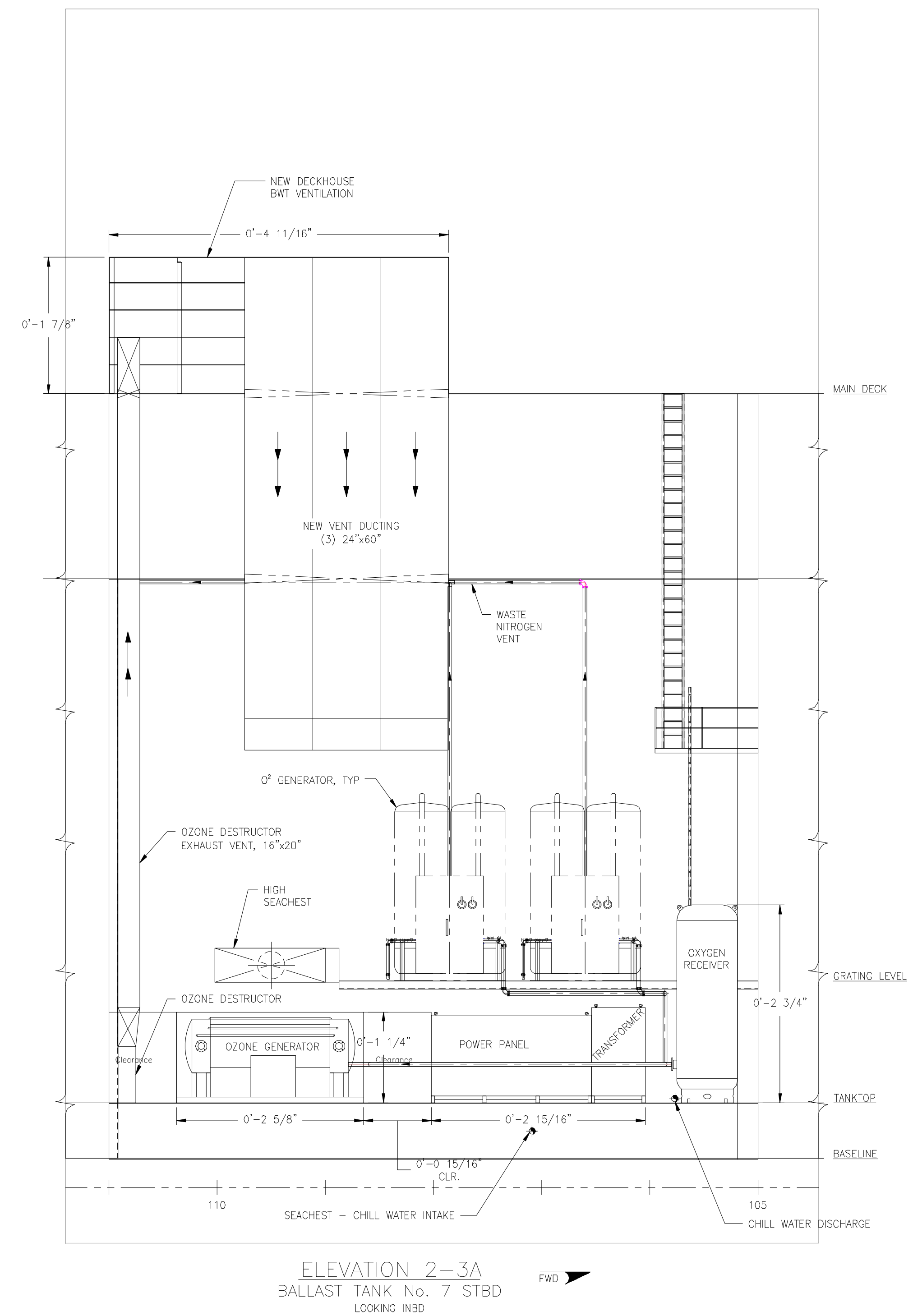


Figure B-3. Vessel Two, BWT System 2 (ozone BWT System): general arrangement and piping installation (2 of 4).

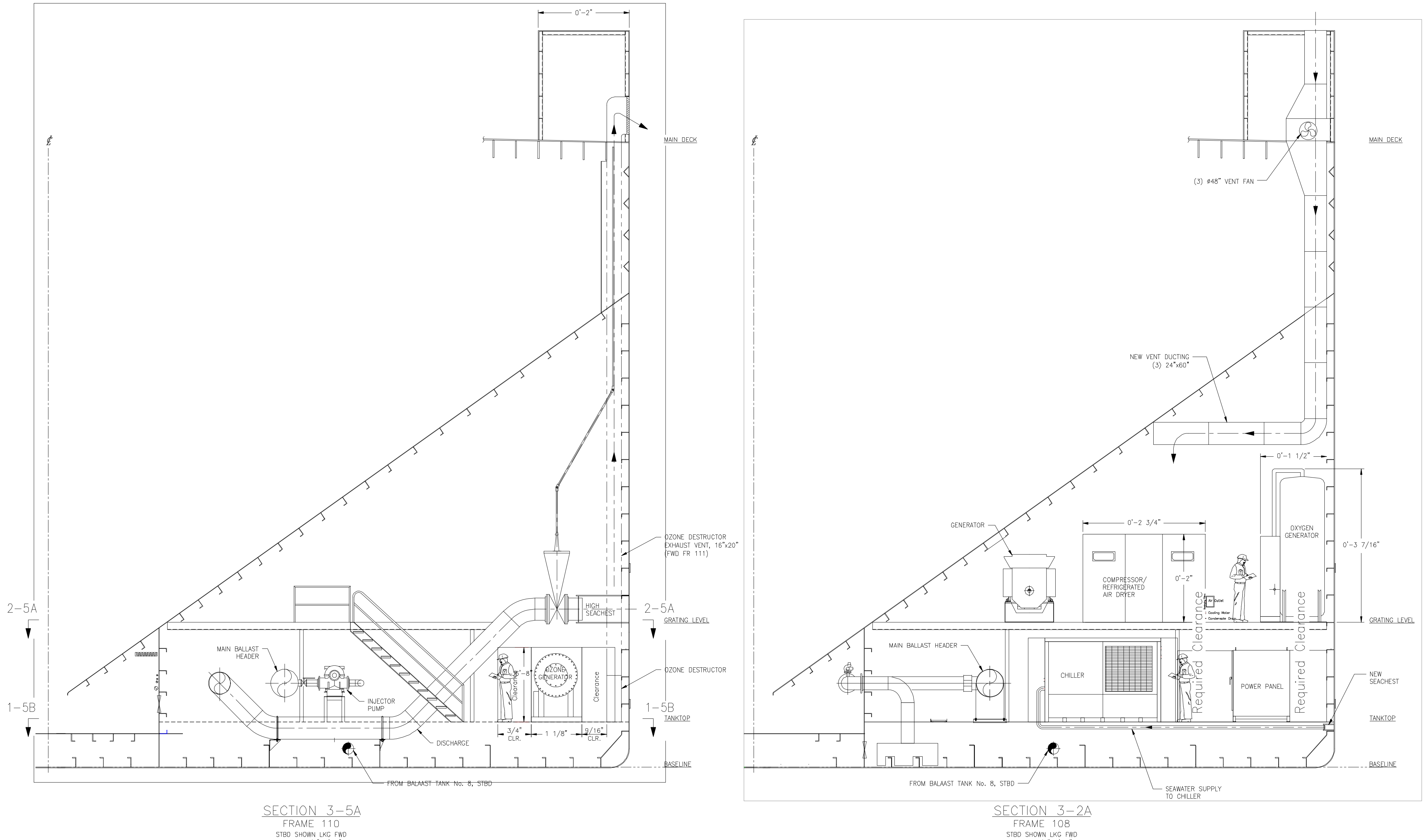


Figure B-3. Vessel Two, BWT System 2 (ozone BWT System): general arrangement and piping installation (3 of 4).

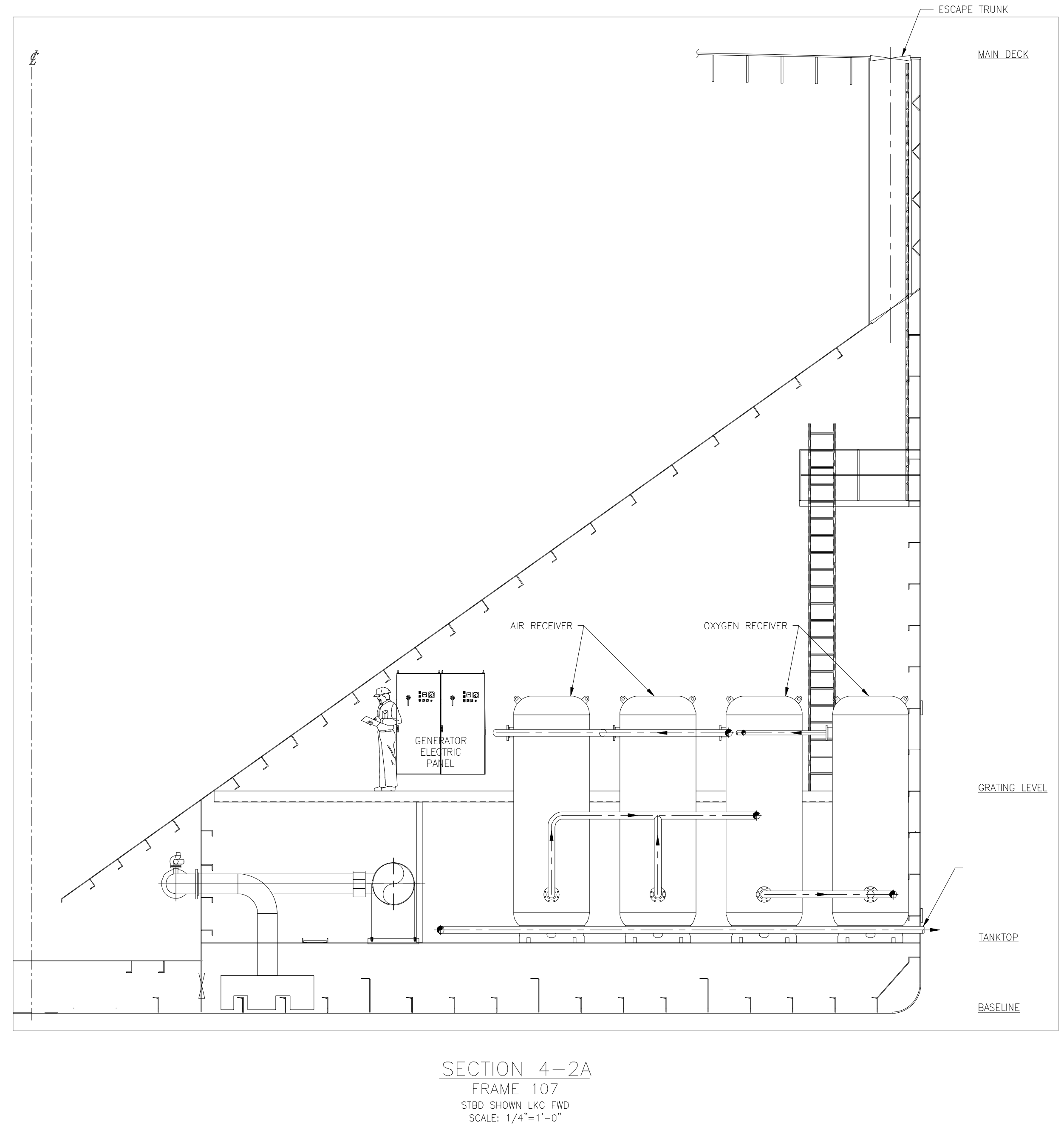


Figure B-3. Vessel Two, BWT System 2 (ozone BWT System): general arrangement and piping installation (4 of 4).

MATERIAL SCHEDULE

SERVICE	SIZE	PIPE	TAKEDOWN JOINTS MATERIAL	TAKEDOWN JOINTS GASKETS	TAKEDOWN JOINTS BOLTING	FITTINGS	VALVES BODY	VALVES TRIM	REMARKS
BALLAST WATER	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28	BUTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS	
COMPRESSED AIR	ALL	SCH 40 STAINLESS STEEL SEAMLESS ASTM A-312, GR 316L ANSI B16.10	150# FLANGE, SLIP-ON STAINLESS STEEL ASTM A-182, GR 316L ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	SCH 80 STAINLESS STEEL, ASTM A-182 TYPE 316, ANSI B16.9	ALL TYPES, ASTM A351, GRADE CF8M, AISI TYPE 316 STAINLESS STEEL FLANGED 150#, ANSI B1.10 & B16.34	REMOVABLE SEATS. A316 STAINLESS STEEL OR MONEL DISK, STAINLESS STEEL STEM	
COMPRESSED OXYGEN	ALL	SCH 40 STAINLESS STEEL SEAMLESS ASTM A-312, GR 316L ANSI B16.10	150# FLANGE, SLIP-ON STAINLESS STEEL ASTM A-182, GR 316L ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	SCH 80 STAINLESS STEEL, ASTM A-182 TYPE 316, ANSI B16.9	ALL TYPES, ASTM A351, GRADE CF8M, AISI TYPE 316 STAINLESS STEEL FLANGED 150#, ANSI B1.10 & B16.34	REMOVABLE SEATS. A316 STAINLESS STEEL OR MONEL DISK, STAINLESS STEEL STEM	
OZONE	ALL	SCH 40 STAINLESS STEEL SEAMLESS ASTM A-312, GR 316L ANSI B16.10	150# FLANGE, SLIP-ON STAINLESS STEEL ASTM A-182, GR 316L ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	SCH 80 STAINLESS STEEL, ASTM A-182 TYPE 316, ANSI B16.9	ALL TYPES, ASTM A351, GRADE CF8M, AISI TYPE 316 STAINLESS STEEL FLANGED 150#, ANSI B1.10 & B16.34	REMOVABLE SEATS. A316 STAINLESS STEEL OR MONEL DISK, STAINLESS STEEL STEM	

SYMBOLS LIST

Symbol	Description
	PIPE W/ FLOW DIRECTION
	EXISTING PIPE W/ FLOW DIRECTION
R-1	AIR RECIEVER
R-2	OXYGEN RECIEVER
TRO	TOTAL RESIDUAL OXIDANTS METER
PI	PRESSURE INDICATOR
	FLOW CONTROL VALVE
	PRESSURE REGULATOR
DP	DIFFERENTIAL PRESSURE INDICATOR
	CENTRIFUGAL PUMP
	OZONE INJECTOR
FM	MICRON FILTER
FC	COALESCING FILTER
	CROSSING PIPES CONNECTED
	CROSSING PIPES NOT CONNECTED
	SEACHEST
	INCLUDED WITH BALLAST WATER TREATMENT SYSTEM
	OVERBOARD DISCHARGE
	GLOBE VALVE
	BHD/DECK PENETRATION
A	REMOTE ACTUATED DOUBLE ACTING BUTTERFLY VALVE (OPEN/CLOSE)
	GATE VALVE

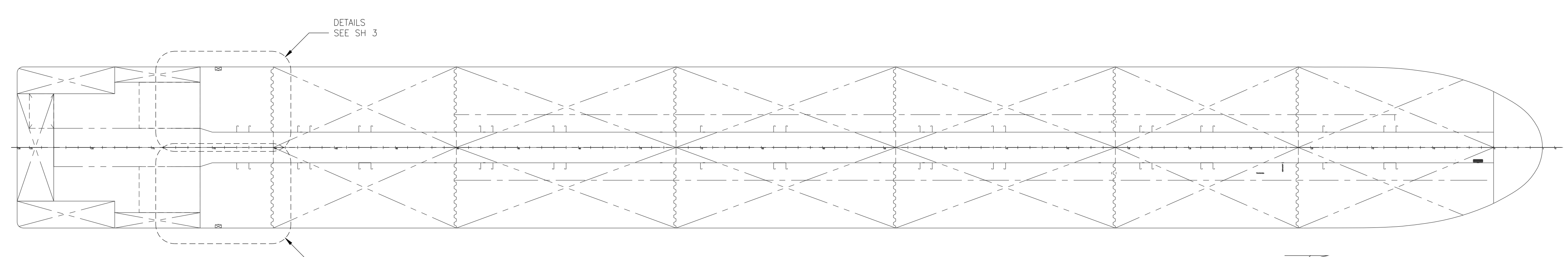
MAJOR EQUIPMENT LIST

QTY.	ITEM	MAKE	MODEL	CAPACITY	DRIVE/NOTES
2	AIR COMPRESSOR	ATLAS COPCO	GA160FF	928 SCFM @ 125 PSI	ELECTRIC
2	COALESCING FILTERS	–	–	928 SCFM @ 125 PSI	–
2	AIR RECEIVER	OGSI	AST-1550/OST-1550	204 CU FT	–
2	OXYGEN GENERATOR	OGSI	OG-4000	67 SCFM @ 45 PSI	ELECTRIC
2	OXYGEN RECEIVER	OGSI	AST-1550/OST-1550	204 CU FT	–
2	0.01 MICRON FILTER	–	–	67 SCFM @ 45 PSI	–
1	OZONE GENERATOR	ITT WEDECO	PDO 2500	131 SCFM @ 15 PSI	ELECTRIC
2	CHILLER	FILTRINE	POC-8000-860	630,000 BTU/HR	ELECTRIC
2	GATE VALVE	–	–	ø5"	–
1	CHECK VALVE	–	–	ø5"	–
2	CHECK VALVE	–	–	ø1 1/2"	–
2	BUTTERFLY VALVE	–	–	ø12"	ELECTRIC ACTUATOR

NOTE: QUANTITIES LISTED ARE FOR BOTH SIDES OF SHIP.

PUMP LIST

QTY.	SERVICE	TYPE	MODEL	CAPACITY	DRIVE
2	STRIPPING PUMP (EXISTING)	CENTRIFUGAL	–	3,000 GPM	–
4	MAIN BALLAST PUMP (EXISTING)	CENTRIFUGAL	ALLIS CHALMERS, MODEL WSDV	13,000 GPM	200 HP ELECTRIC MOTOR
2	OZONE INJECTION PUMP (NEW)	CENTRIFUGAL	GOULDS PUMPS, MODEL 3410 M 6x8-11	1,200 GPM AT 100 FT HEAD	50 HP ELECTRIC MOTOR
4	CHILLER CIRCULATING PUMP (NEW)	CENTRIFUGAL	GOULDS PUMPS, MODEL 2ST1H5B2	80 GPM AT 75 FT HEAD	3 HP ELECTRIC MOTOR



KEY PLAN 1-4A
LARGE CAPACITY 1000' LAKER
TANK ARRANGEMET

Figure B-4. Vessel Two, BWT System 2 (ozone BWT System): piping diagram (1 of 3).

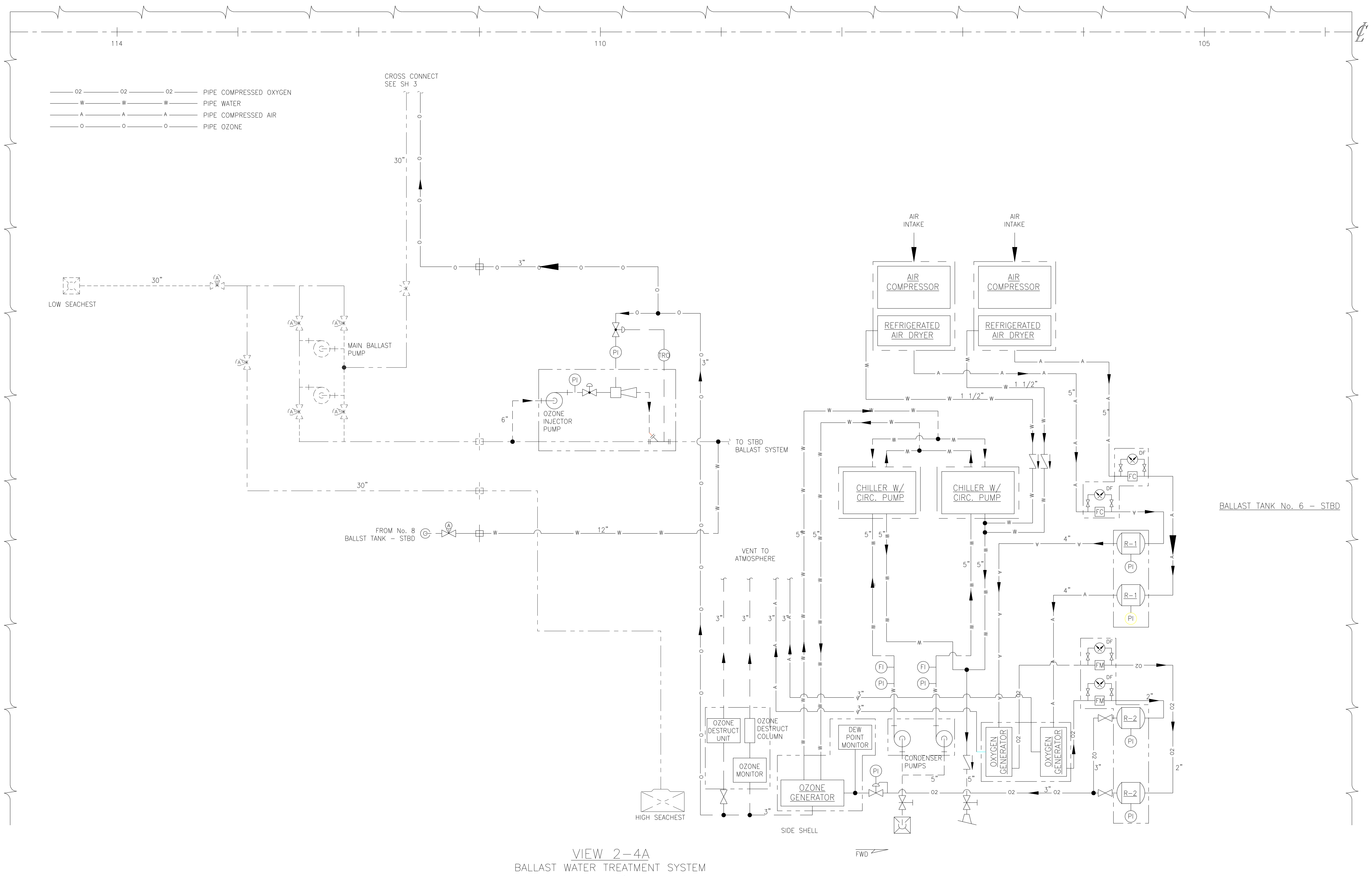


Figure B-4. Vessel Two, BWT System 2 (ozone BWT System): piping diagram (2 of 3).

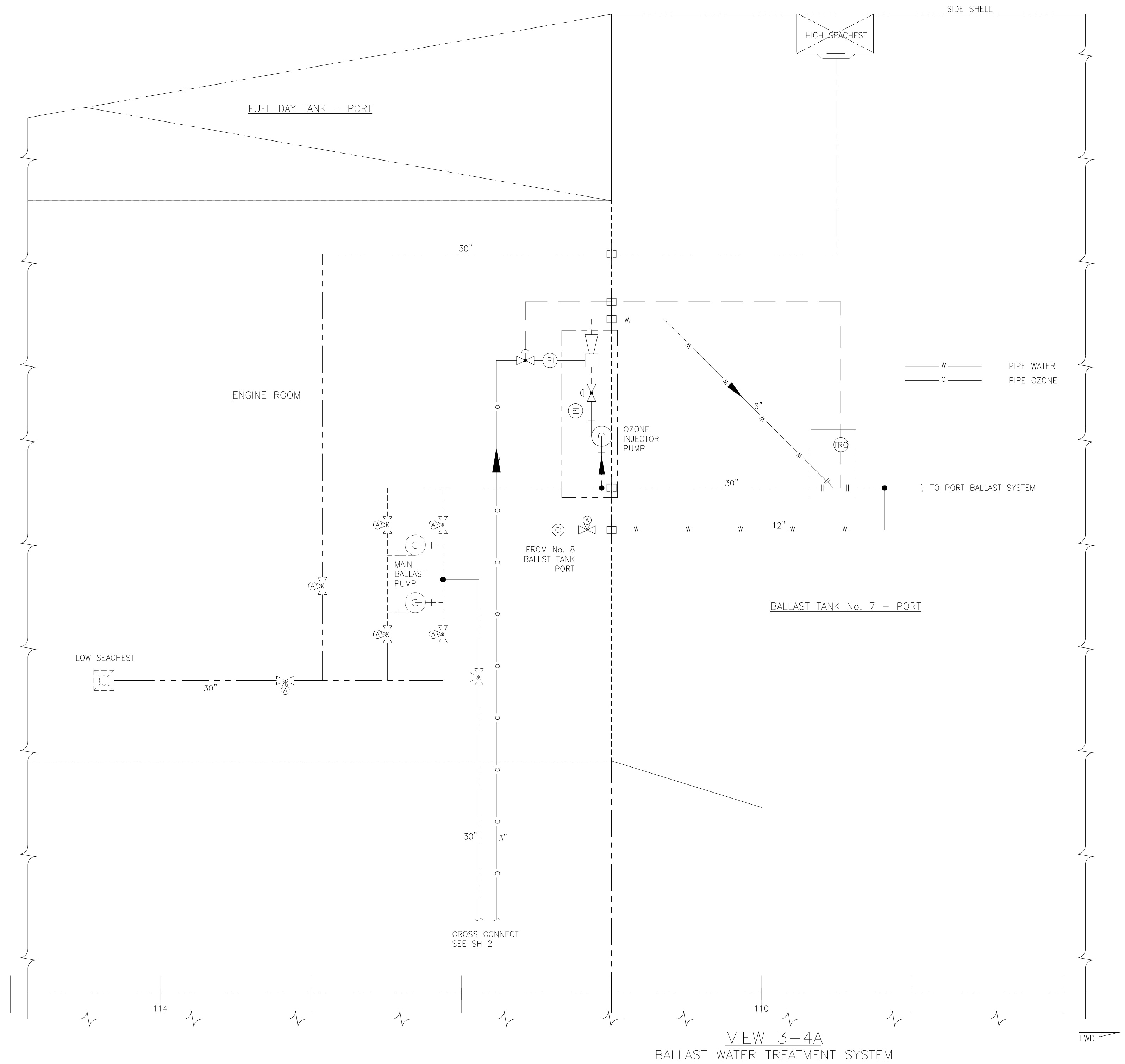


Figure B-4. Vessel Two, BWT System 2 (ozone BWT System): piping diagram (3 of 3).

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APPENDIX C VESSEL THREE (OLDER, SMALL CAPACITY 700' – 800' LAKER): SUPPORTING DOCUMENTS

C.1 Vessel Three, BWT System 1: Supporting Data

C.1.1 Vessel Three, BWT System 1: Electrical Loads Analysis

The addition of the BWT increases the electrical load on the vessel. The BWT system load is an additional 931 kW, the vessel electrical system requires an additional 385 kW to accommodate the new BWT systems. See Table C-1 for a calculation of the additional electrical requirements.

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Table C-1. Vessel Three, BWT System 1: electrical loads summary.

EQUIPMENT LIST - FOR GENSET SIZING																			
		Qty.		**MECHANICAL INFO**				**ELECTRICAL LOADS INFO**											**Comments**
SWBS						Mech Motor Rating				Demand Load (At Sea)		Demand Load (Docking)		Demand Load (Loading)		Demand Load (Unloading)		Power Source	
No. Item	Description	Qty.	Units	Manufacturer	Model	Value	Unit	eKW	Voltage	Duty	eKW	Duty	eKW	Duty	eKW	Duty	eKW	(E/M/B)	
100 Hull/Structural																			
200 Propulsion Plant																			
200 Propulsion	Existing propulsion equipment	1	ea	N/A	N/A	163.0	ekW	163.0	450/3P	0.1	16.0	0.4	64.0	0.0	0.0	0.0	0.0	M	From existing electrical load analysis
300 Electric Plant																			
330 Lighting	Existing lighting system	1	ea	N/A	N/A	96.0	ekW	96.0	120/1P	0.7	67.2	0.7	67.2	0.6	59.5	0.7	67.2	M	From existing electrical load analysis
320 Machine shop	Existing machine shop receptacles	1	ea	N/A	N/A	35.2	ekW	35.2	120/1P	0.0	0.6	0.0	0.5	0.0	0.0	0.0	0.5	M	From existing electrical load analysis
324 UV power panel(N)	BWT - UV power supply panel	19	ea	UV + Filter Vendor	3535HSC8	N/A													
324 BWT control panel(N)	BWT - system control panel	19	ea	UV + Filter Vendor	GCS-01	0.3	ekW	5.7	208/1P	1.0	5.7	0.0	0.0	1.0	5.7	1.0	5.7	B	From vendor proposal
400 Navigation/Communications																			
500 Auxiliary Systems																			
524 Ballast system	Existing ballast pumps	1	ea	N/A	N/A	248.0	ekW	248.0	450/3P	0.0	0.0	0.0	0.0	0.7	180.0	0.7	180.0	M	From existing electrical load analysis
500 Ship service auxiliary	Existing ship service auxiliary	1	ea	N/A	N/A	608.9	ekW	608.9	450/3P	0.3	162.9	0.3	152.4	0.3	171.5	0.4	251.4	M	From existing electrical load analysis
511 Heating	Existing heating	1	ea	N/A	N/A	1.0	ekW	1.0	120/1P	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	M	From existing electrical load analysis
512 Ventilation system	Existing ventilation	1	ea	N/A	N/A	86.8	ekW	86.8	450/3P	0.9	76.4	0.9	74.0	0.7	64.4	0.7	59.6	M	From existing electrical load analysis
568 Deck equipment	Existing deck equipment	1	ea	N/A	N/A	257.6	ekW	257.6	450/3P	0.0	0.0	0.0	0.0	0.3	73.2	0.3	67.3	M	From existing electrical load analysis
500 Miscellaneous	Existing miscellaneous equip.	1	ea	N/A	N/A	6.6	ekW	6.6	450/3P	5.5	36.3	0.0	0.0	0.0	0.0	0.0	0.0	M	From existing electrical load analysis
529 Filter unit	BWT filter assembly	152	ea	UV + Filter Vendor	4" Filter (6 pack)	N/A												B	From system vendor information
529 UV reactor	UV lamp reactor	19	ea	UV + Filter Vendor	160835	34.0	ekW	646.0	480/3P	0.5	323.0	0.0	0.0	1.0	646.0	1.0	646.0	B	From system vendor information
568 Bow thruster auxiliary	Existing bow thruster	1	ea	N/A	N/A	804.0	ekW	804.0	450/3P	0.0	0.0	1.0	804.0	0.0	0.0	0.0	0.0	M	From existing electrical load analysis
529 Backwash pump	Backwash pump	19	ea	UV + Filter Vendor	ABZCH2	15.0	ekW	285.000	208/1P	0.5	142.5	0.0	0.0	1.0	285.0	1.0	285.0	B	From system vendor information
600 Outfit and Furnishings																			
650 Galley	Existing galley equipment	1	ea	N/A	N/A	82.4	ekW	82.4	208/1P	0.3	24.2	0.3	21.8	0.3	21.8	0.3	21.8	M	From existing electrical load analysis
Total Load											854.9		1183.9		1507.2		1584.6		
Required Generator Rating	Rated power at 100% MCR					100%	MCR				854.9		1183.9		1507.2		1584.6		
Available Generator Power		2				600.0	ekW				1200.0		1200.0		1200.0		1200.0		
Remaining Power Required											**0.0**		**0.0**		**307.2**		**384.6**		

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C.1.2 Vessel Three, BWT System 1: Deadweight Analysis

The light ship weight of the vessel increases because of the addition of the BWT system, generator and electrical system installation, and ancillary system changes. The weight change decreases the cargo carrying capacity of the vessel. Table C-2 contains the weight change summary.

Table C-2. Vessel Three, BWT System 1: weight estimate.

	VESSEL WEIGHT ESTIMATE						
SWBS No.	Description	Qty.	Total Wt. (lbs)	LCG (+ aft)	TCG (+ stbd)	VCG (+ abl)	Notes
	SUMMARY						
100	STRUCTURE CHANGES		17,361				
200	MACHINERY CHANGES		10,275				
300	ELECTRICAL CHANGES		34,020				
400	ELECTRONICS & IC CHANGES		0				
500	AUXILIARY SYSTEMS CHANGES		95,935				
600	OUTFIT CHANGES		1,295				
	VESSEL WEIGHT CHANGE - SUBTOTAL		158,886 (70.93LT)				
	Add Margin to Structure for Roll & Weld	3%	520				
	STRUCTURE	15%	2,604				
	ELECTRICAL	20%	6,804				
	AUXILIARY SYSTEMS	20%	19,187				
	OUTFIT	20%	259				
	VESSEL WEIGHT CHANGE WITH MARGINS		**188,260 (80.04 LT)**				
	Minimum Loadline Draft			Keel Draft:	26.4 ft		Summer draft LL
	OLD AVAILABLE DEADWEIGHT		57,346,240 (25,601.00 LT)				
	NEW AVAILABLE DEADWEIGHT		**57,157,980 (25,516.96 LT)**		**Lost Capacity 0.3%**		

C.1.3 Vessel Three, BWT System 1: Cost Estimate

The vessel will have to be modified for the installation of the BWT. Structural changes and existing system will have to be modified. The modification will require accesses to be cut and repaired. The summary cost is $8,897,039 (Table C-3).

C.1.4 Vessel Three, BWT System 1: System Installation Drawings

The vessel structure and mechanical system will be modified for the BWT systems. The general arrangement and structural changes are shown in Figure C-1. Piping modifications are shown in Figure C-2.

Table C-3. Vessel Three, BWT System 1: cost estimate summary.

PRELIMINARY COST ESTIMATE SUMMARY: SHIPBOARD FILTRATION & UV BWT SYSTEM										
SWBS No.	**Item Description**	**Labor Hours**	**Material & Services @ Cost ($)**	**Subcontracts @ Cost ($)**	**Labor Cost @ $70/Hr**	**Material & Services w/17% Mark-up ($)**	**Subcontracts w/8% Mark-up ($)**	**Item Total Costs**	**Percent of Total Cost**
000	Project Management & Admin	302	$209,597	$202,384	$21,168	$245,228	$218,575	$484,971	5.52%
100	Structure	6188	$61,023	$--	$433,160	$71,397	$--	$504,557	5.75%
200	Propulsion Machinery	0	$--	$--	$-	$--	$--	$--	0.00%
300	Electrical System	3274	$300,788	$--	$229,148	$351,922	$--	$581,070	5.29%
400	Add'l Fire Extinguishers in Mach'y Spaces	4402	$96,410	$--	$308,112	$112,799	$--	$420,911	4.79%
500	Auxiliary Systems	8350	$82,258	$3,432,423	$584,472	$96,242	$3,707,016	$4,387,731	49.97%
600	Outfitting	632	$12,454	$--	$44,218	$14,572	$--	$58,789	0.67%
700	Mission Specific Equipment	0	$--	$--	$-	$--	$--	$--	0.00%
800	Integration & Engineering	108	$430,248	$159,040	$7,526	$503,390	$171,763	$682,680	7.78%
900	Shipyard Support Services	4068	$59,147	$76,899	$284,749	$69,202	$83,051	$437,002	4.98%
	Contingency @ 18% **Based on Concept Design Level**							**$1,339,328**	**15.25%**
	Totals for all Items	**27322**	**$951,137**	**$3,870,746**	**$1,912,552**	**$1,581,752**	**$4,180,406**	**$8,897,039**	**100%**

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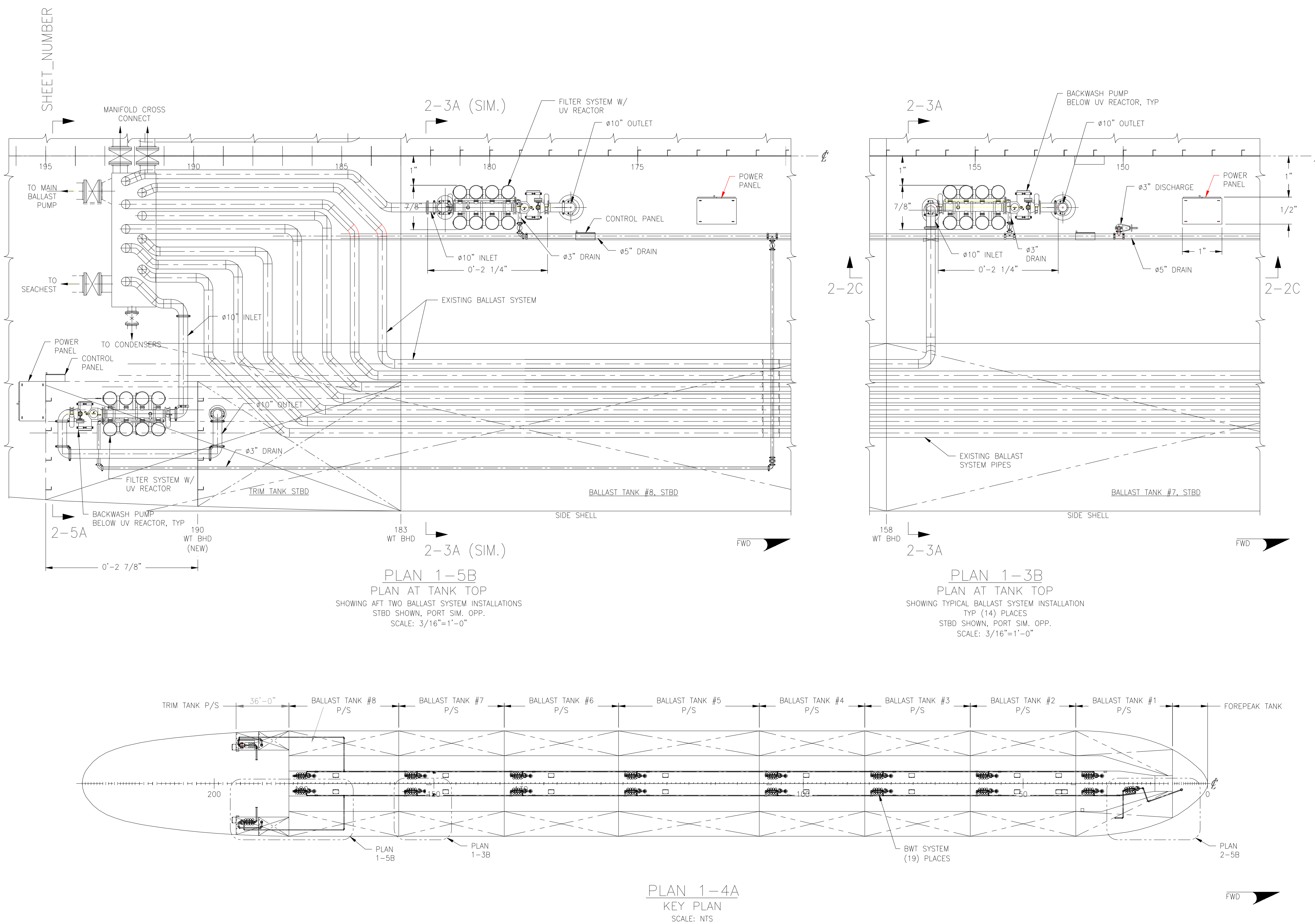

Figure C-1. Vessel Three, BWT System 1 (filter/UV BWT System): general arrangement (1 of 2).

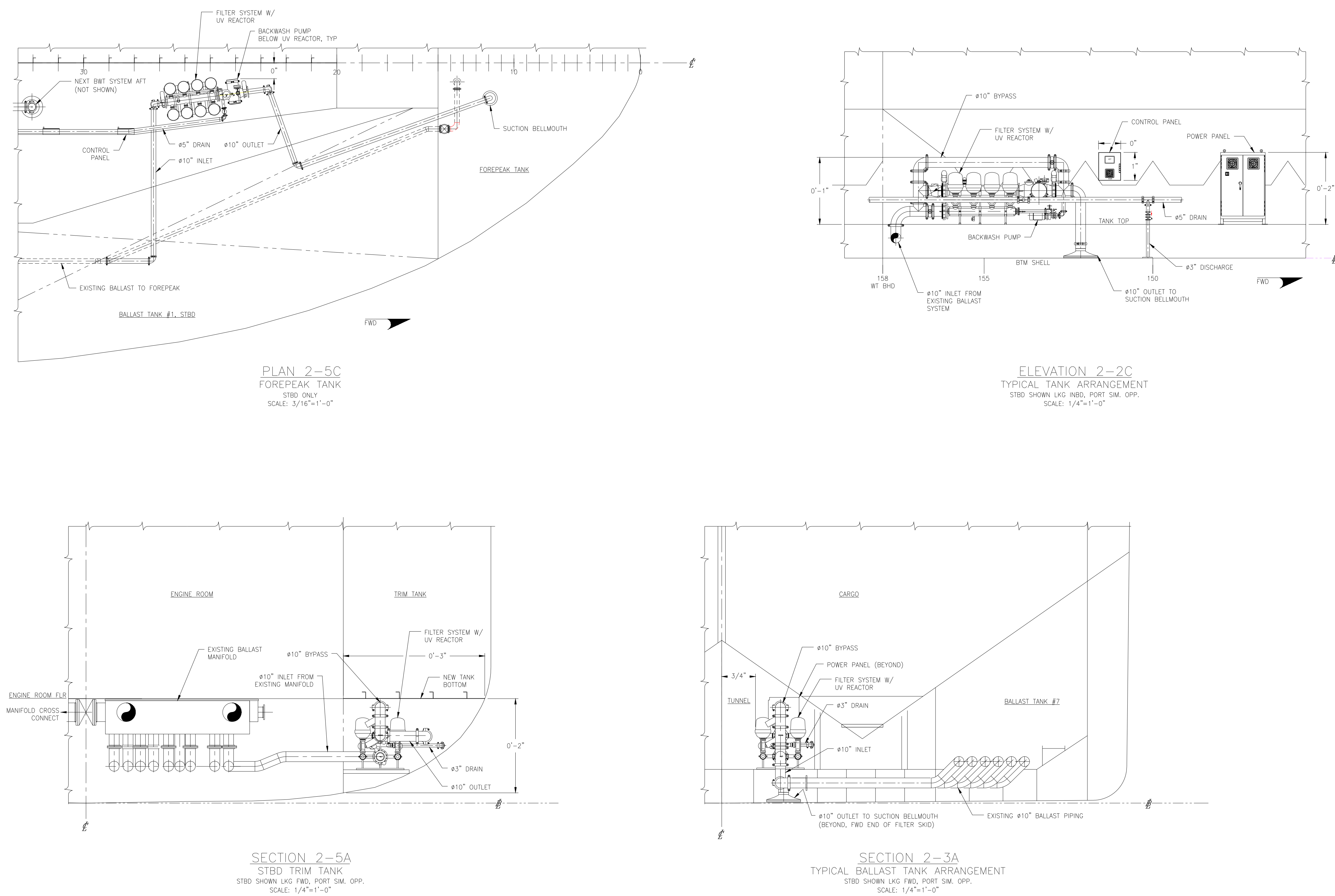

Figure C-1. Vessel Three, BWT System 1 (filter/UV BWT System): general arrangement (2 of 2).

SYMBOLS LIST	
	PIPE W/ FLOW DIRECTION
	EXISTING PIPE W/ FLOW DIRECTION
	PNEUMATIC CONTROLLED DOUBLE ACTING BUTTERFLY VALVE (OPEN/CLOSE)
	SINGLE FILTER
	BUTTERFLY VALVE
	FILTER SYSTEM
	UV CHAMBER
	SWING CHECK VALVE
DPS	DIFFERENTIAL PRESSURE SWITCH
	CENTRIFUGAL PUMP
	FLANGED CONNECTION
	REDUCER
	CROSSING PIPES CONNECTED
	CROSSING PIPES NOT CONNECTED
	PNEUMATIC CONTROLLED 3-WAY VALVE
	GATE VALVE
	BELLMOUTH
	PIPE DOWN
	BHD/DECK PENETRATION
	REMOTE ACTUATED DOUBLE ACTING BUTTERFLY VALVE (OPEN/CLOSE)
	INCLUDED WITH BALLAST WATER TREATMENT SYSTEM

MATERIAL SCHEDULE

SERVICE	SIZE	PIPE	TAKEDOWN JOINTS			FITTINGS	VALVES		REMARKS
			MATERIAL	GASKETS	BOLTING		BODY	TRIM	
BALLAST WATER (BWT SYSTEM CONNECTIONS)	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28	BUTTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS	
BALLAST WATER (ALL OTHER COMPONENTS)	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	VICTAULIC SLIP ON COUPLING CARBON STEEL 150# ASTM A105 ANSI B16.5	VICTAULIC GRADE E OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28	BUTTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS	

MAJOR EQUIPMENT LIST

QTY.	ITEM	MAKE	MODEL	CAPACITY	DRIVE/NOTES
2	3" GATE VALVE	–	–	–	–
2	3" SWING CHECK VALVE				
19	10" BUTTERFLY				
19	1/2" BUTTERFLY VALVE				

PUMP LIST

QTY.	SERVICE	TYPE	MODEL	CAPACITY	DRIVE
2	MAIN BALLAST PUMP (EXISTING)	CENTRIFUGAL	ALLIS CHALMERS LSV	10,500 GPM AT 40 FT HEAD	150 HP ELECTRIC MOTOR
2	AUXILIARY BALLAST PUMP (EXISTING)	CENTRIFUGAL	–	2,000 GPM	ELECTRIC MOTOR
19	BACKWASH PUMP (NEW)	CENTRIFUGAL	ABZCH2	265 GPM AT 167 FT HEAD	ELECTRIC MOTOR

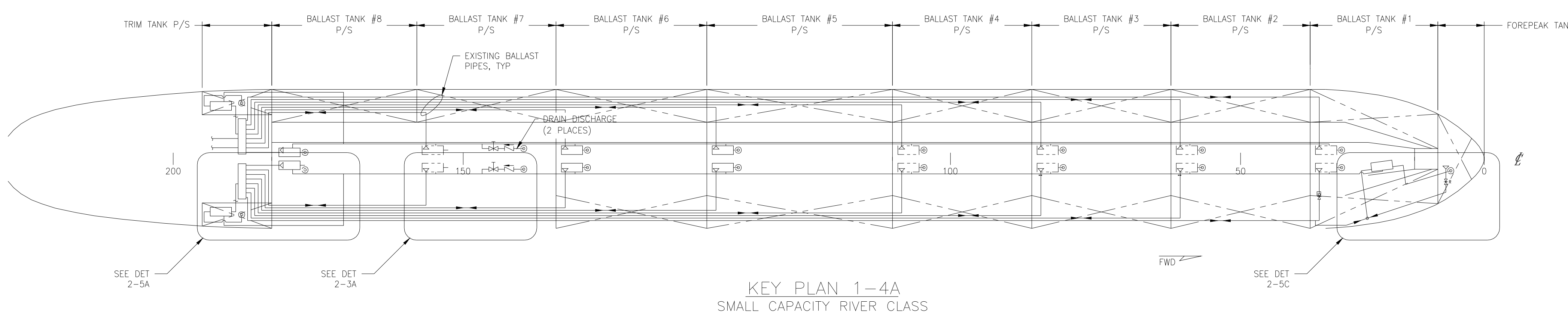

Figure C-2. Vessel Three, BWT System 1 (filter/UV BWT System): piping diagram (1 of 2).

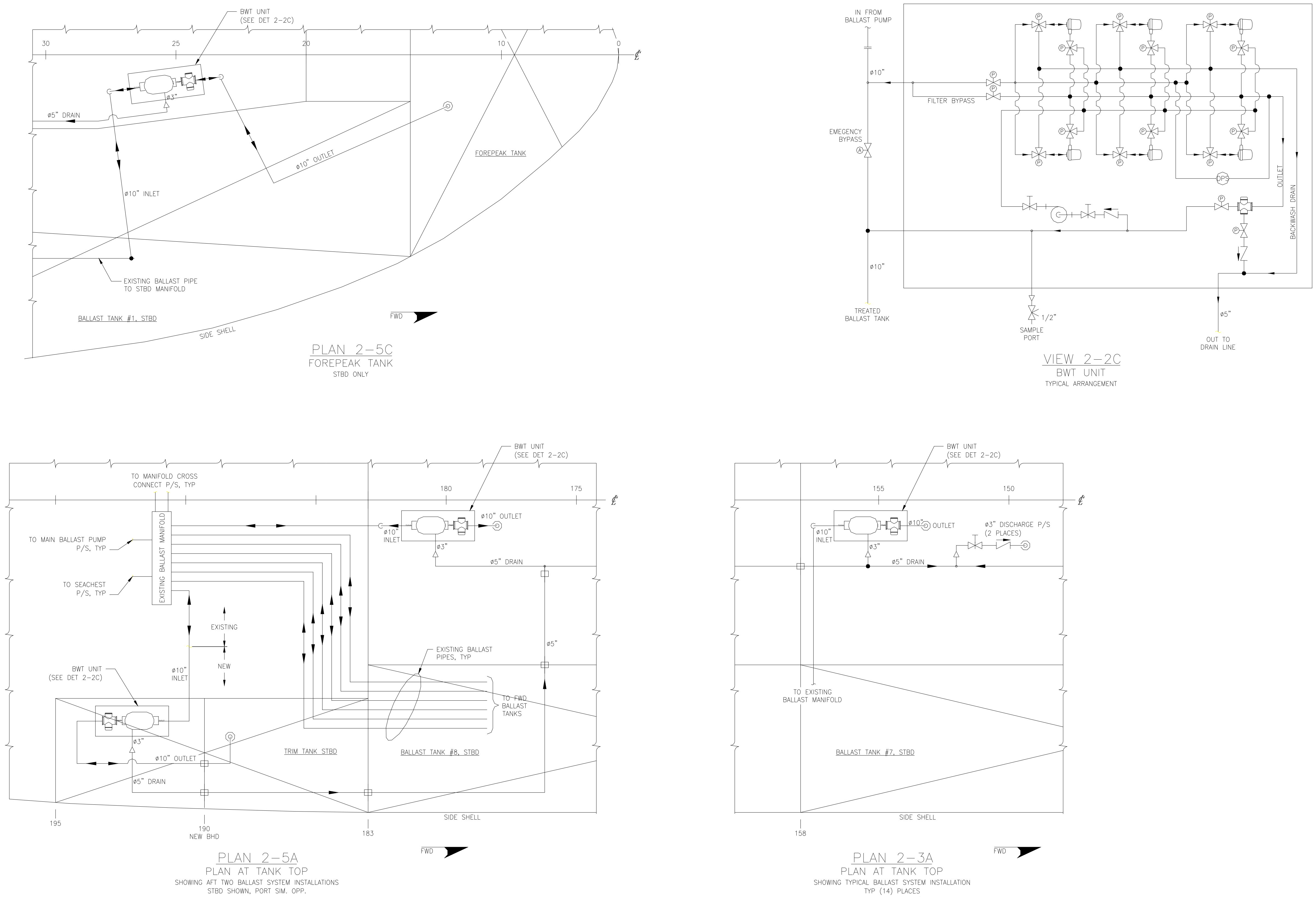

Figure C-2. Vessel Three, BWT System 1 (filter/UV BWT System): piping diagram (2 of 2).

C.2 Vessel Three, BWT System 2: Supporting Data

C.2.1 Vessel Three, BWT System 2: Ozone Ventilation

The ozone BWT system is located in a single space. The system has a large air requirement to operate; see Table C-4.

Table C-4. Vessel Three, BWT System 2: ventilation calculations.

Summary

This spreadsheet performs calculations to determine required ventilation for new BWT machinery space.

Air Requirements for Machinery

Item	*Formula*	*Value*	*Units*
Air compressor 1 inlet	Qc1 =	7,891.16	*cfm*
Total air requirement	Qt1 = Qc1	7,891.16	*cfm*
Extra air provided for adequate ventilation	Qt2 = 2 * Qt1	15,782.31	*cfm*
New ventilation required	**Qt = Qt2**	**15,782.31**	***cfm***
Ventilation per fan	**Qf = Qt**	**15,782.31**	***cfm***

Selected Fan

Make	*Model*	*Dimensions*		*Units*
Hartzell	A48---366DA---ST___4	Size	36.00	*in*
		Static Pressure	0.75	*in*
		Flow Rate	17,299.00	*cfm*
		Motor RPM	1,160.00	*rpm*
		Motor Power	4.10	*Hp*

C.2.2 Vessel Three, BWT System 2: Electrical Loads Analysis

The addition of the BWT increases the electrical load on the vessel. The BWT system requires 450 kW, but when added to the existing vessel load, remains within the existing 1200 kW electrical system capacity. See Table C-5 for a calculation of the additional electrical requirements.

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Table C-5. Vessel Three, BWT System 2: electrical loads summary.

EQUIPMENT LIST - FOR GENSET SIZING																			
		Qty.		**MECHANICAL INFO**				**ELECTRICAL LOADS INFO**											**Comments**
SWBS						Mech Motor Rating				Demand Load (At Sea)		Demand Load (Docking)		Demand Load (Loading)		Demand Load (Unloading)		Power Source	
No. Item	Description	Qty.	Units	Manufacturer	Model	Value	Unit	eKW	Voltage	Duty	eKW	Duty	eKW	Duty	eKW	Duty	eKW	(E/M/B)	
100 Hull/Structural																			
200 Propulsion Plant																			
200 Propulsion	Existing propulsion equipment	1	ea	N/A	N/A	163.0	ekW	163.0	450/3P	0.1	16.0	0.4	64.0	0.0	0.0	0.0	0.0	M	From existing electrical load analysis
300 Electric Plant																			
330 Lighting	Existing lighting system	1	ea	N/A	N/A	96.0	ekW	96.0	120/1P	0.7	67.2	0.7	67.2	0.6	59.5	0.7	67.2	M	From existing electrical load analysis
320 Machine shop	Existing machine shop receptacles	1	ea	N/A	N/A	35.2	ekW	35.2	120/1P	0.0	0.6	0.0	0.5	0.0	0.0	0.0	0.5	M	From existing electrical load analysis
324 Power panel for BWT (N)	Power for ozone generator	1	ea	Ozone Vendor	-			0	450/3P	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	B	From vendor data
324 Transformer for BWT (N)	High voltage trans for ozone generator.	1	ea	Ozone Vendor	-			0	450/3P	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.0	B	From vendor data
400 Navigation/Communications																			
500 Auxiliary Systems																			
524 Ballast system	Existing ballast pumps	1	ea	N/A	N/A	248.0	ekW	248.0	450/3P	0.0	0.0	0.0	0.0	0.7	180.0	0.7	180.0	M	From existing electrical load analysis
500 Ship service auxiliary	Existing ship service auxiliary	1	ea	N/A	N/A	608.9	ekW	608.9	450/3P	0.3	162.9	0.3	152.4	0.3	171.5	0.4	251.4	M	From existing electrical load analysis
511 Heating	Existing heating	1	ea	N/A	N/A	1.0	ekW	1.0	120/1P	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	M	From existing electrical load analysis
512 Ventilation system	Existing ventilation	1	ea	N/A	N/A	86.8	ekW	86.8	450/3P	0.9	76.4	0.9	74.0	0.7	64.4	0.7	59.6	M	From existing electrical load analysis
568 Deck equipment	Existing deck equipment	1	ea	N/A	N/A	257.6	ekW	257.6	450/3P	0.0	0.0	0.0	0.0	0.3	73.2	0.3	67.3	M	From existing electrical load analysis
500 Miscellaneous	Existing miscellaneous equip.	1	ea	N/A	N/A	6.6	ekW	6.6	450/3P	5.5	36.3	0.0	0.0	0.0	0.0	0.0	0.0	M	From existing electrical load analysis
568 Bow thruster auxiliary	Existing bow thruster	1	ea	N/A	N/A	804.0	ekW	804.0	450/3P	0.0	0.0	1.0	804.0	0.0	0.0	0.0	0.0	M	From existing electrical load analysis
529 Air compressor (N)	Compressor for ozone system	1	ea	Ozone Vendor	GA160	125.0	kW	139.9	450/3P	1.0	139.9	0.0	0.0	0.0	0.0	1.0	139.9	B	From vendor proposal, scaled for capacity
529 Air receiver (N)	Receiver for compressed air	1	ea	Ozone Vendor	AST-1550/OST-1550	0.0	kW			1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	B	From vendor proposal, scaled for capacity
529 Oxygen generator (N)	Oxygen generator from comp. air	1	ea	Ozone Vendor	OG-4000	0.060	kW	0.1	120/1P	1.0	0.1	0.0	0.0	0.0	0.0	1.0	0.1	B	From vendor proposal, scaled for capacity
529 Oxygen receiver (N)	Oxygen receivers	1	ea	Ozone Vendor	AST-1550/OST-1550	0.0	kW			1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.0	B	From vendor proposal, scaled for capacity
529 Ozone generator (N)	Ozone generator	1	ea	Ozone Vendor	PDO 2500	150.0	kW	166.8	480/3P	1.0	166.8	0.0	0.0	0.0	0.0	1.0	166.8	B	From vendor proposal, scaled for capacity
529 Chiller unit (N)	Chiller for ozone generator	1	ea	Ozone Vendor	POC-8000-860	59.3	kW	68.0	230/3P	1.0	68.0	0.0	0.0	0.0	0.0	1.0	68.0	B	From vendor proposal, scaled for capacity
529 Condenser pump (N)	Condenser pump for chillers	1	ea	Ozone Vendor	2ST	3.0	HP	2.9	230/3P	1.0	2.9	0.0	0.0	0.0	0.0	1.0	2.9	B	From vendor proposal, scaled for capacity
529 Ozone injector pumps (N)	Ozone injection into main ballast line	2	ea	Ozone Vendor	3410 M 6x8-11	40.0	HP	69.4	230/3P	1.0	69.4	0.0	0.0	0.0	0.0	1.0	69.4	B	From vendor proposal, scaled for capacity
512 Ventilation fan (N)	Supplemental ventilation for comp.	1	ea	Hartzell	A48---366DA---ST__4	4.1	HP	3.9	450/1P	1.0	3.9	0.3	1.3	0.3	1.2	1.0	3.9	M	From fan vendor spec
600 Outfit and Furnishings																			
650 Galley	Existing galley equipment	1	ea	N/A	N/A	82.4	ekW	82.4	208/1P	0.3	24.2	0.3	21.8	0.3	21.8	0.3	21.8	M	From existing electrical load analysis
Total Load											834.7		1185.2		571.6		1098.8		
Required Generator Rating	Rated power at 100% MCR					100%	MCR				834.7		1185.2		571.6		1098.8		
Available Generator Power		2				600.0	ekW				1200.0		1200.0		1200.0		1200.0		
Remaining Power Required											**0.0**		**0.0**		**0.0**		**0.0**		

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C.2.3 Vessel Three, BWT System 2: Deadweight Analysis

The light ship weight of the vessel increases because of the addition of the BWT system, its electrical system installation, and ancillary system changes. The weight change decreases the cargo carrying capacity of the vessel. Table C-6 contains the weight change summary. Table C-7, Table C-8, and Table C-9 contain the detailed weight change estimate.

Table C-6. Vessel Three, BWT System 2: weight estimate summary.

	OZONE SYSTEM INSTALL WEIGHT ESTIMATE		
SWBS No.	Description	Qty.	Total Wt. (lbs)
	SUMMARY		
100	STRUCTURE		12,596
200	MACHINERY		79,062
300	ELECTRICAL		1,964
	OZONE SYSTEM WEIGHT		**93,622 (41.8 LT)**

Table C-7. Vessel Three, BWT System 2: structure weight estimate.

SWBS No.	Description	Qty.	Unit Wt. (lbs)	Total Wt. (lbs)
100	**Structure** Estimate for equipment foundations	15%	83972	12,596
	STRUCTURE - SUBTOTAL			12596 (5.6 LT)

Table C-8. Vessel Three, BWT System 2: machinery weight estimate.

SWBS No.	Description	Qty.	Unit Wt. (lbs)	Total Wt. (lbs)
200	**Machinery**	1.00	13700	13,700
	Ozone Generator	1.00	13700	13,700
	Ozone Gen. Power Panel	1.00	10000	10,000
	Ozone Gen. HV Transformer	1.00	5200	5,200
	Air Compressors	1.00	7412	7,412
	Air Receivers	1.00	2600	2,600
	Oxygen Generators	1.00	14500	14,500
	Oxygen Receivers	1.00	2600	2,600
	Chillers	1.00	6500	6,500
	Condenser Water Pumps	1.00	100	100
	Ozone Injector Pumps	2.00	150	300
	1.5" pipe	150	2.72	408
	2" pipe	100	3.65	365
	3" pipe	150	7.58	1,137
	4" pipe	50	10.79	540
	MACHINERY - SUBTOTAL			79062 (35.3 LT)

Table C-9. Vessel Three, BWT System 2: electrical weight estimate.

SWBS No.	Description	Qty.	Unit Wt. (lbs)	Total Wt. (lbs)
300	**Electrical**			
	switchboards, wiring, and aux. systems	1	1964	1,964
	ELECTRICAL - SUBTOTAL			1,964 (0.9 LT)

C.2.4 Vessel Three, BWT System 2: Cost Estimate

The vessel will have to be modified for the installation of the BWT. Structural changes and existing system will have to be modified. The modification will require accesses to be cut and repaired. The summary cost is $3,457,000; see Table C-10.

C.2.5 Vessel Three, BWT System 2: System Installation Drawings

The vessel structure and mechanical system will be modified for the BWT systems. The general arrangement and structural changes are shown in Figure C-3. Piping modifications are shown in Figure C-4.

Table C-10. Vessel Three, BWT System 2: cost estimate.

PRELIMINARY COST ESTIMATE SUMMARY: SHIPBOARD OZONE BWT SYSTEM									
SWBS No.	**Item Description**	**Labor Hours**	**Material & Services @ Cost ($)**	**Subcontracts @ Cost ($)**	**Labor Cost @$70/Hr**	**Material & Services w/17% Mark-up ($)**	**Subcontracts w/8% Mark-up ($)**	**Item Total Costs**	**Percent of Total Cost**
000	Project Management & Admin	184	$253,257	$--	$12,870	$296,310	$--	$309,180	8.94%
100	Structure	3812	$39,069	$--	$266,808	$45,711	$--	$312,519	9.04%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	1834	$17,171	$--	$128,402	$20,090	$--	$148,492	4.30%
400	Add'l Fire Extinguishers in Mach'y Spaces	493	$4,480	$--	$34,496	$5,242	$--	$39,738	1.15%
500	Auxiliary Systems	3520	$47,972	$1,121,680	$246,396	$56,127	$1,211,414	$1,513,937	43.80%
600	Outfitting	659	$13,182	$--	$46,099	$15,423	$--	$61,523	1.78%
700	Mission Specific Equipment	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	108	$267,008	$--	$7,526	$312,399	$--	$319,926	9.25%
900	Shipyard Support Services	2188	$37,516	$25,126	$153,194	$43,893	$27,136	$224,223	6.49%
	Contingency @ 18%							**$527,317**	**15.25%**
	Based on Concept Design Level								
	Totals for all Items	**12797**	**$679,654**	**$1,146,806**	**$895,790**	**$795,196**	**$1,238,551**	**$3,456,853**	**100%**

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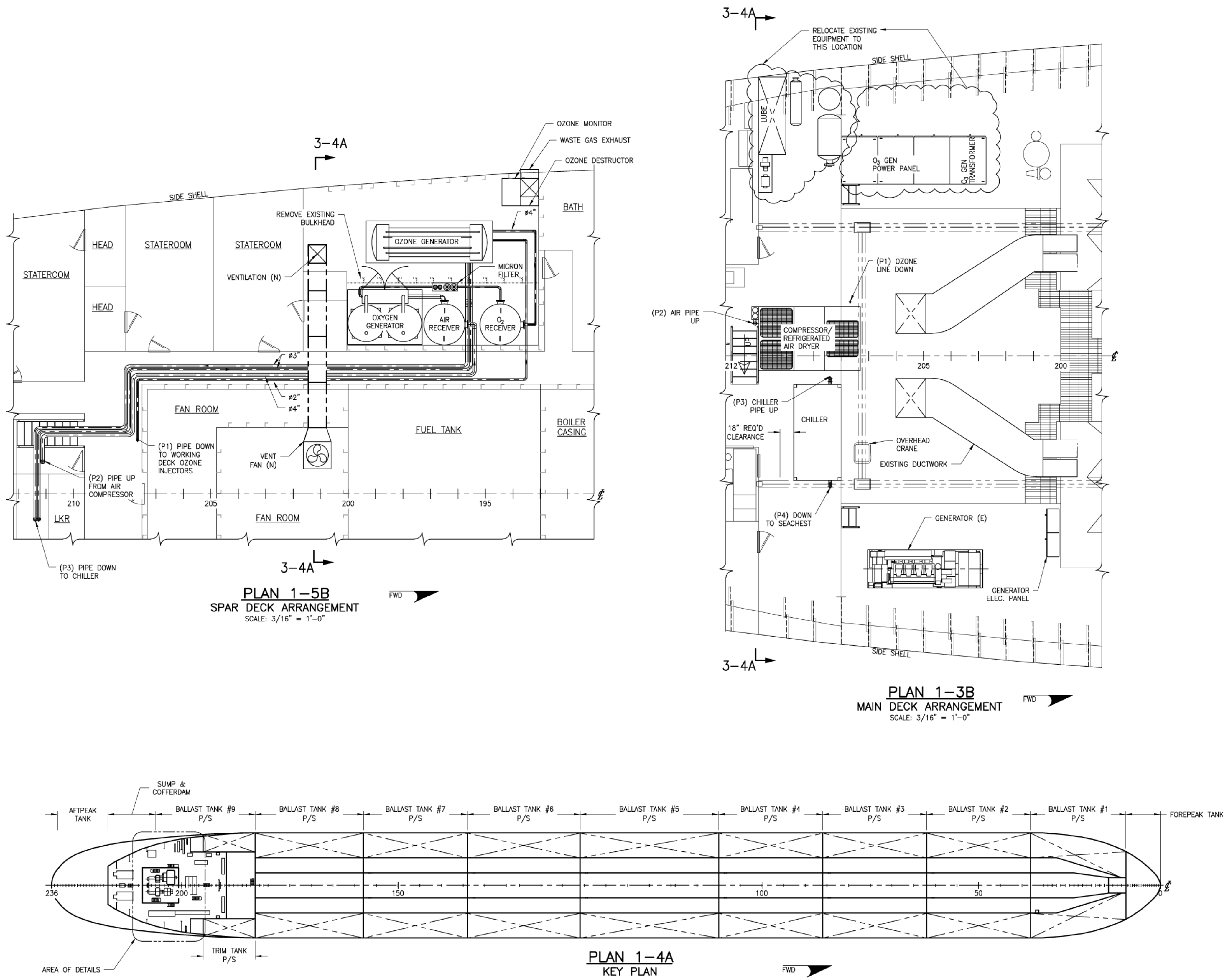
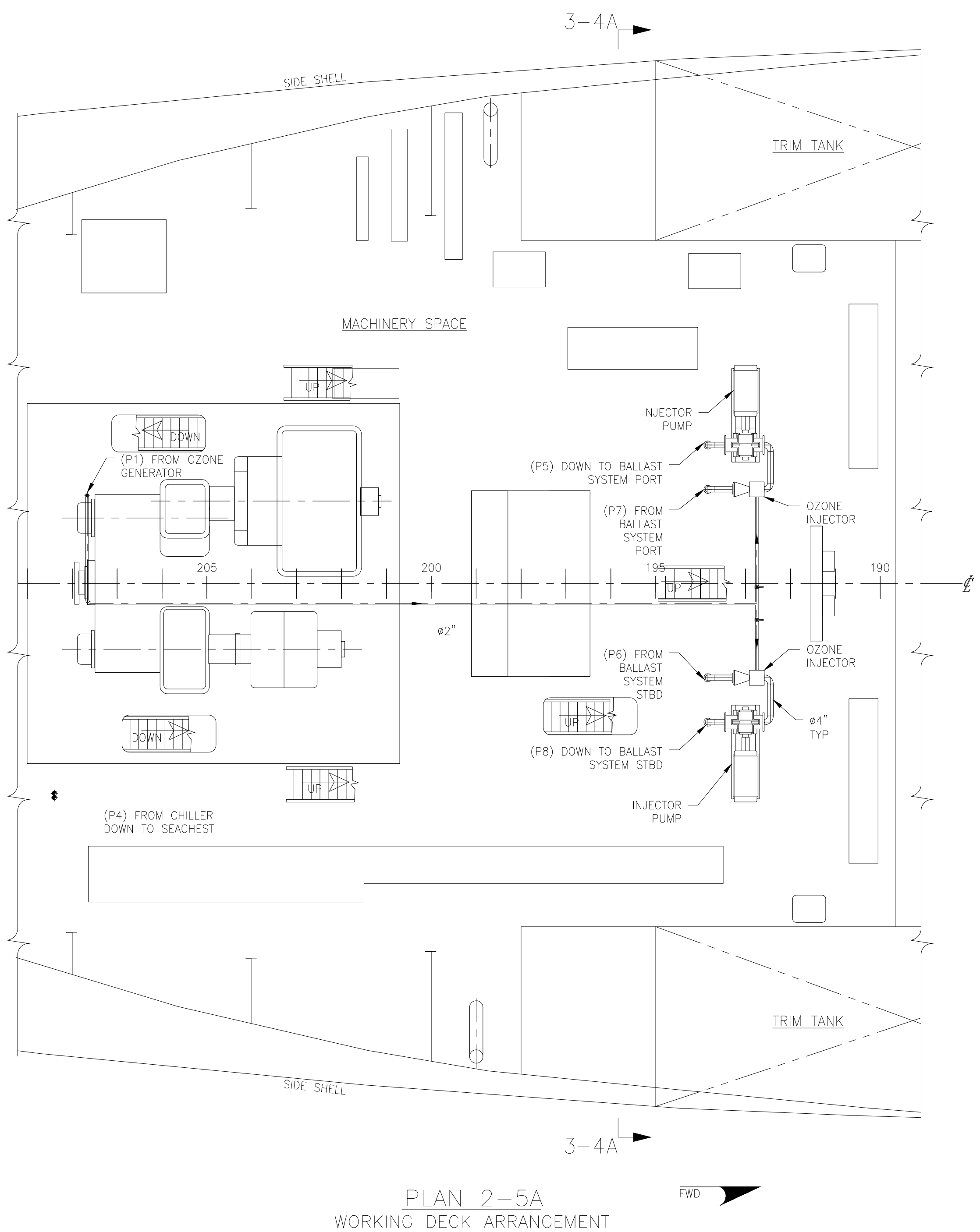


Figure C-3. Vessel Three, BWT System 2 (ozone BWT System): general arrangement (1 of 3).



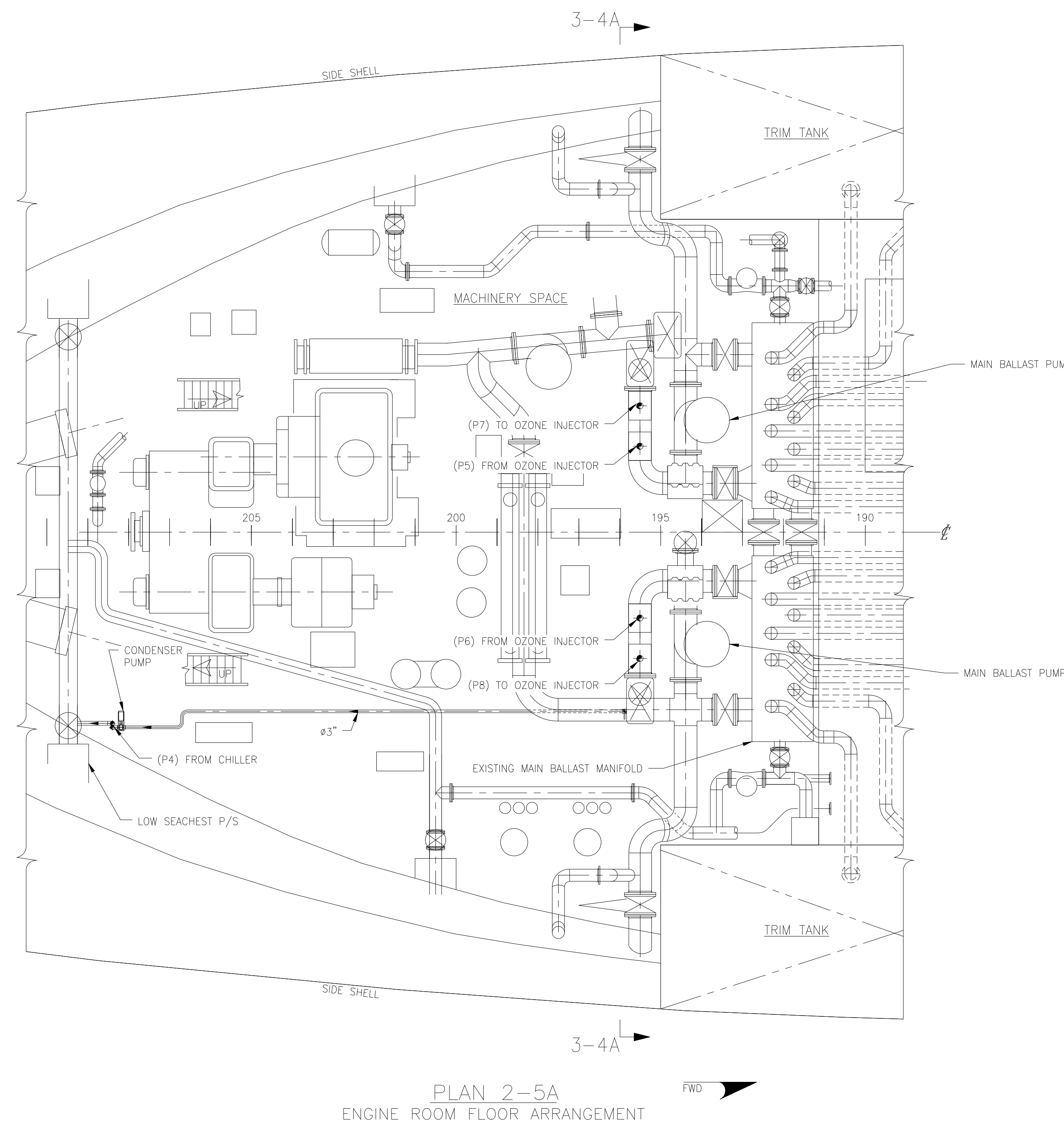
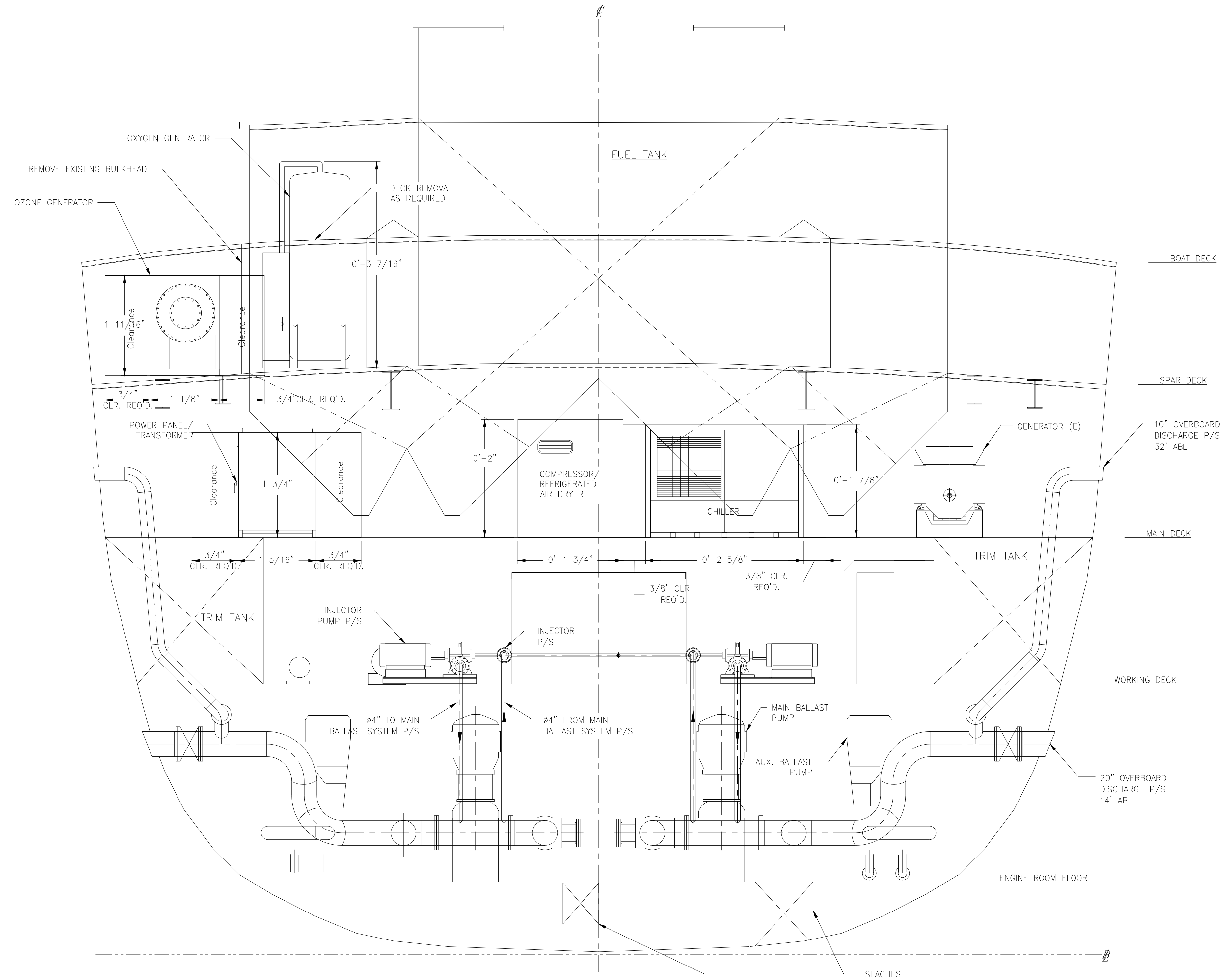


Figure C-3. Vessel Three, BWT System 2 (ozone BWT System): general arrangement (2 of 3).



SECTION 3-4A
LOOKING FORWARD
FRAME LOCATION VARIES TO SHOW SIZES AND LOCATIONS

Figure C-3. Vessel Three, BWT System 2 (ozone BWT System): general arrangement (3 of 3).

SYMBOLS LIST

Symbol	Description
	NEW PIPE W/ FLOW DIRECTION
	EXISTING PIPE W/ FLOW DIRECTION
R-1	AIR RECEIVER
R-2	OXYGEN RECEIVER
RO	TOTAL RESIDUAL OXIDANTS METER W/ ELECTRIC CABLE CONNECTION
PI	PRESSURE INDICATOR
	FLOW CONTROL VALVE
	PRESSURE REGULATOR
DP	DIFFERENTIAL PRESSURE INDICATOR
	CENTRIFUGAL PUMP
	OZONE INJECTOR
FM	.01 MICRON FILTER
FC	COALESCING FILTER
	CROSSING PIPES CONNECTED
	CROSSING PIPES NOT CONNECTED
	SEACHEST
	INCLUDED WITH BALLAST WATER TREATMENT SYSTEM
	OVERBOARD DISCHARGE
	GLOBE VALVE
	BHD PENETRATION
	REMOTE ACTUATED DOUBLE ACTING BUTTERFLY VALVE (OPEN/CLOSE)
	GATE VALVE W/ REMOTE OPERATOR
	OZONE WATER MIXING Y-FITTING
	SUCTION BELLMOUTH
	DECK PENETRATION – PIPE DOWN
	CHECK VALVE

MATERIAL SCHEDULE

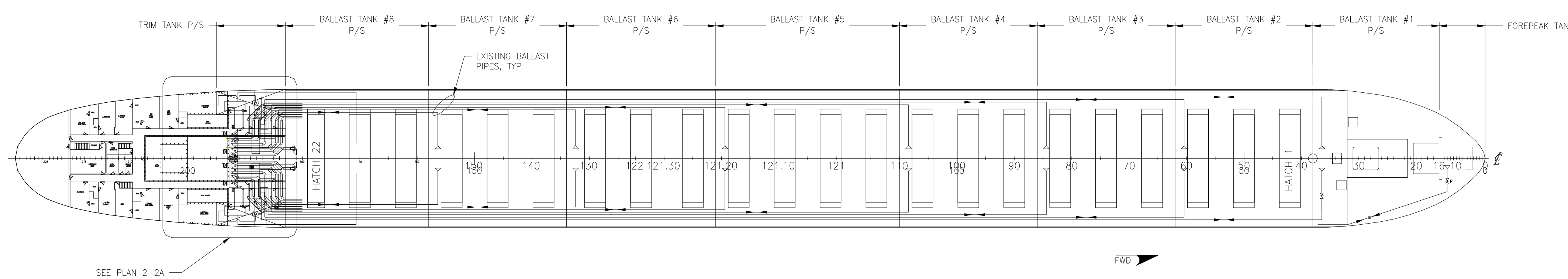
SERVICE	SIZE	PIPE	TAKEDOWN JOINTS			FITTINGS	VALVES	
			MATERIAL	GASKETS	BOLTING		BODY	TRIM
BALLAST WATER	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28	BUTTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS
COMPRESSED AIR	ALL	SCH 40 STAINLESS STEEL SEAMLESS ASTM A-312, GR 316L ANSI B16.10	150# FLANGE, SLIP-ON STAINLESS STEEL ASTM A-182, GR 316L ANSI B16.5	GARLOCK GYLON STYLE 3510 OR EQUAL	316 STAINLESS	SCH 40 STAINLESS STEEL, ASTM A-182 TYPE 316, ANSI B16.9	ALL TYPES, ASTM A351, GRADE CF8M, AISI TYPE 316 STAINLESS STEEL FLANGED 150#, ANSI B1.10 & B16.34	REMOVABLE SEATS. A316 STAINLESS STEEL OR MONEL DISK, STAINLESS STEEL STEM
COMPRESSED OXYGEN	ALL	SCH 40 STAINLESS STEEL SEAMLESS ASTM A-312, GR 316L ANSI B16.10	150# FLANGE, SLIP-ON STAINLESS STEEL ASTM A-182, GR 316L ANSI B16.5	--	316 STAINLESS	SCH 40 STAINLESS STEEL, ASTM A-182 TYPE 316, ANSI B16.9	ALL TYPES, ASTM A351, GRADE CF8M, AISI TYPE 316 STAINLESS STEEL FLANGED 150#, ANSI B1.10 & B16.34	REMOVABLE SEATS. A316 STAINLESS STEEL OR MONEL DISK, STAINLESS STEEL STEM
OZONE	ALL	SCH 40 STAINLESS STEEL SEAMLESS ASTM A-312, GR 316L ANSI B16.10	150# FLANGE, SLIP-ON STAINLESS STEEL ASTM A-182, GR 316L ANSI B16.5	GARLOCK GYLON STYLE 3510 OR EQUAL	316 STAINLESS	SCH 40 STAINLESS STEEL, ASTM A-182 TYPE 316, ANSI B16.9	ALL TYPES, ASTM A351, GRADE CF8M, AISI TYPE 316 STAINLESS STEEL FLANGED 150#, ANSI B1.10 & B16.34	REMOVABLE SEATS. A316 STAINLESS STEEL OR MONEL DISK, STAINLESS STEEL STEM

MAJOR EQUIPMENT LIST

QTY.	ITEM	MAKE	MODEL	CAPACITY	DRIVE/NOTES
2	GATE VALVE	–	–	3"	–
5	BUTTERFLY VALVE	–	–	5"	–
2	BUTTERFLY VALVE	–	–	4"	–

PUMP LIST

QTY.	SERVICE	TYPE	MODEL	CAPACITY	DRIVE
2	MAIN BALLAST PUMP (EXISTING)	CENTRIFUGAL	ALLIS CHALMERS LSV	10,500 GPM AT 40 FT HEAD	150 HP ELECTRIC MOTOR
2	AUXILIARY BALLAST PUMP (EXISTING)	CENTRIFUGAL	–	2,000 GPM	ELECTRIC MOTOR
2	OZONE INJECTOR PUMP (NEW)	CENTRIFUGAL	–	280 GPM AT 300 FT HEAD	40 HP ELECTRIC MOTOR
1	CONDENSER PUMP (NEW)	CENTRIFUGAL	–	75 GPM AT 75 FT HEAD	3 HP ELECTRIC MOTOR



KEY PLAN 1-4A
SMALL CAPACITY RIVER CLASS
EXISTING BALLAST SYSTEM & TANK ARRANGEMENT

Figure C-4. Vessel Three, BWT System 2 (ozone BWT System): piping diagram (1 of 2).

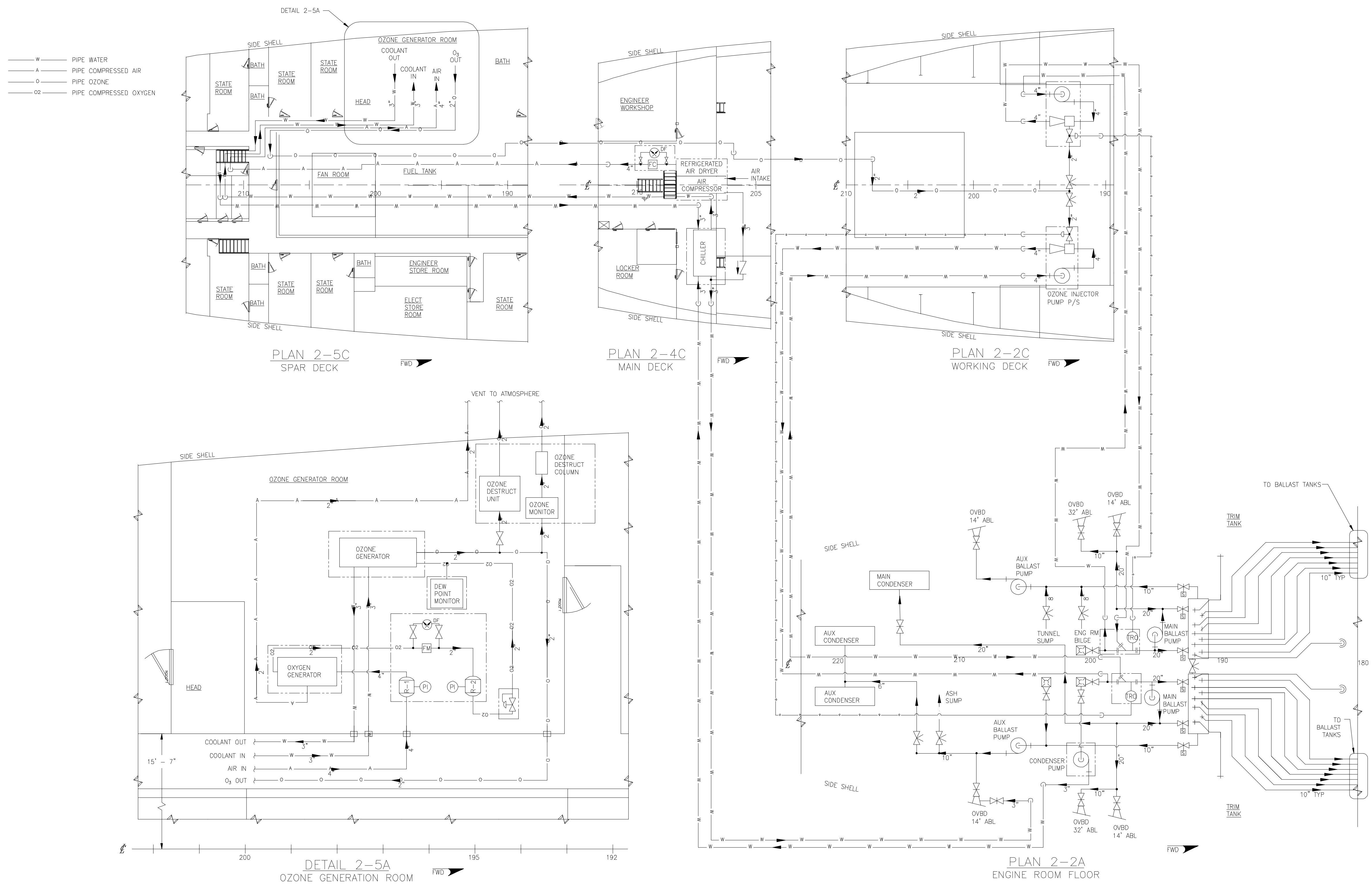


Figure C 4. Vessel Three, BWT System 2 (ozone BWT System): piping diagram (2 of 2).

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APPENDIX D VESSEL FOUR (NEWER, INTERMEDIATE CAPACITY 800' – 900' LAKER): SUPPORTING INFORMATION

D.1 Vessel Four, BWT System 1: Supporting Data

D.1.1 Vessel Four, BWT System 1: Electrical Loads Analysis

The addition of the BWT increases the electrical load on the vessel. The electrical system requires an additional 720 kW to accommodate the new BWT systems. See Table D-1 for a calculation of the additional electrical requirements.

Table D-1. Vessel Four, BWT System 1: electrical load analysis for addition of BWT.

	#	power (kW)	total (kW)
UV Reactors	6	114	684
Backwash Pumps	2	200	400
		Total	**1,084**

D.1.2 Vessel Four, BWT System 1: Deadweight Analysis

The light ship weight of the vessel increases because of the addition of the BWT system, generator and electrical system installation, and ancillary system changes. The weight change decreases the cargo carrying capacity of the vessel. Table D-2 contains the weight change summary.

Table D-2. Vessel Four, BWT System 1: deadweight estimate.

	#	weight (lb)	total (lb)
BWT Systems	2	30,574	61,148
pipe/structure/found	+25%	61,148	15,287
Generators	2	10,275	20,550
switchboards/wiring	+10%	20,550	2,055
enclosures + structure	+50%	20,550	10,275
auxiliary systems	+25%	20,550	5,138
		Total (lb)	**114,453**
		Total (LT)	**51.1**

D.1.3 Vessel Four, BWT System 1: Cost Estimate

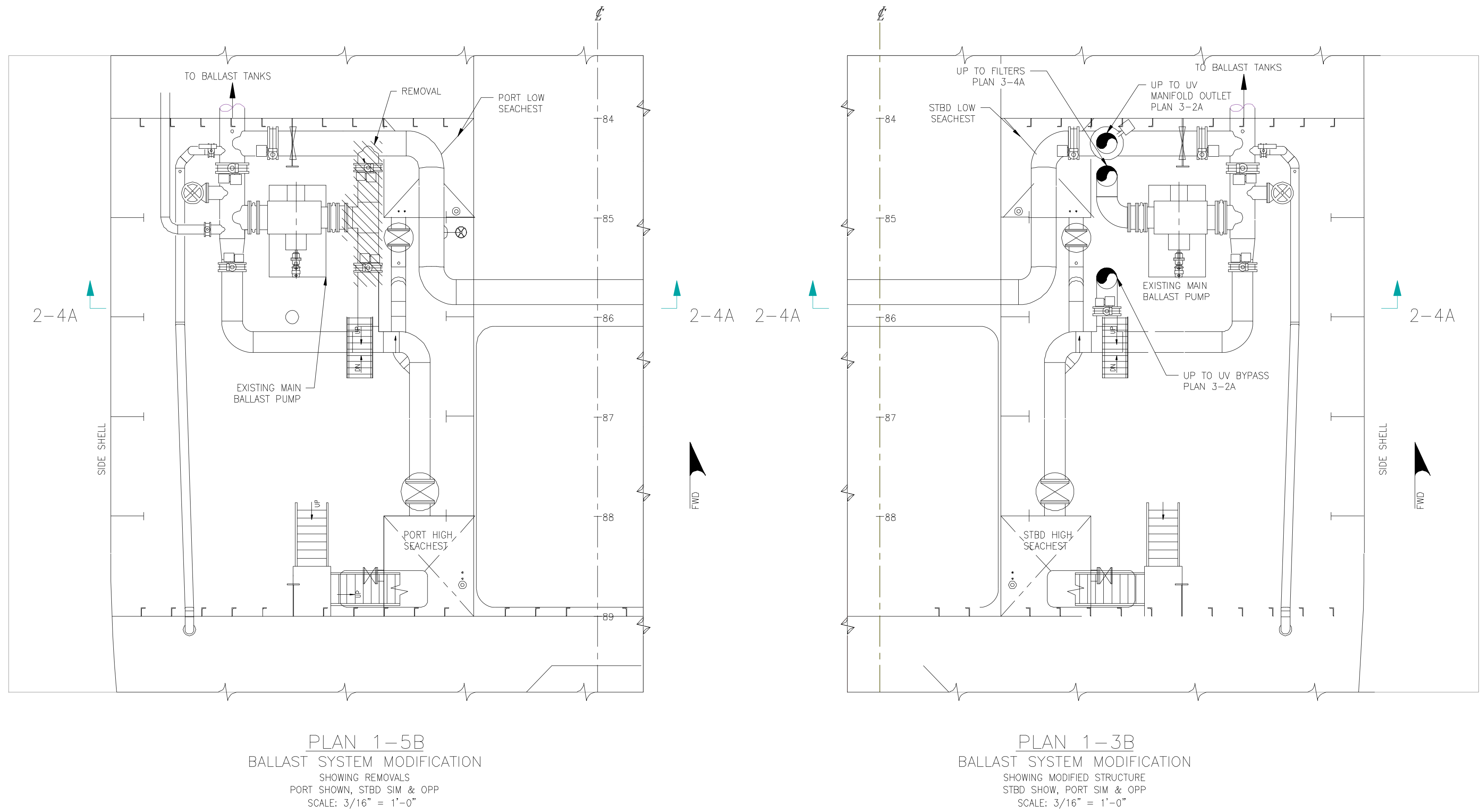
The vessel will have to be modified for the installation of the BWT. Structural changes and existing system will have to be modified. The modification will require accesses to be cut and repaired. The summary cost is $7,944,902; see Table D-3.

D.1.4 Vessel Four, BWT System 1: System Installation Drawings

The vessel structure and mechanical system will be modified for the BWT systems. The general arrangement and structural changes are shown in Figure D-1. Piping modifications are shown in Figure D-2.

Table D-3. Vessel Four, BWT System 1: preliminary cost estimate summary – shipboard filtration/UV BWT system.

SWBS No.	Item Description	Labor Hours	Material & Services @ Cost ($)	Subcontracts @ Cost ($)	Labor Cost @$70/Hr	Material & Services w/17% Mark-up ($)	Subcontracts w/8% Mark-up ($)	Item Total Costs	Percent of Total Cost
000	Project Management & Admin	181	$259,246	$--	$12,701	$303,318	$--	$316,019	3.98%
100	Structure	3881	$54,240	$--	$271,647	$63,461	$--	$335,107	4.22%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	2439	$613,514	$--	$170,755	$717,811	$--	$888,566	11.18%
400	Electronics & IC Systems	161	$3,405	$--	$11,290	$3,984	$--	$15,273	0.19%
500	Auxiliary Systems	3583	$38,839	$3,351,895	$250,803	$45,442	$3,620,047	$3,916,292	49.29%
600	Outfitting	1971	$22,758	$--	$137,984	$26,627	$--	$164,611	2.07%
700	BWT Filter/UV Assemblies	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	108	$32,648	$646,016	$7,526	$38,198	$697,697	$743,422	9.36%
900	Shipyard Support Services	2755	$52,304	$91,392	$192,864	$61,196	$99,617	$353,677	4.45%
	Contingency @ 18%							**$1,211,934**	**15.25%**
	Based on Concept Design Level								
	Totals for all Items	**15080**	**$1,076,954**	**$4,089,303**	**$1,055,570**	**$1,260,037**	**$4,417,361**	**$7,944,902**	**100%**



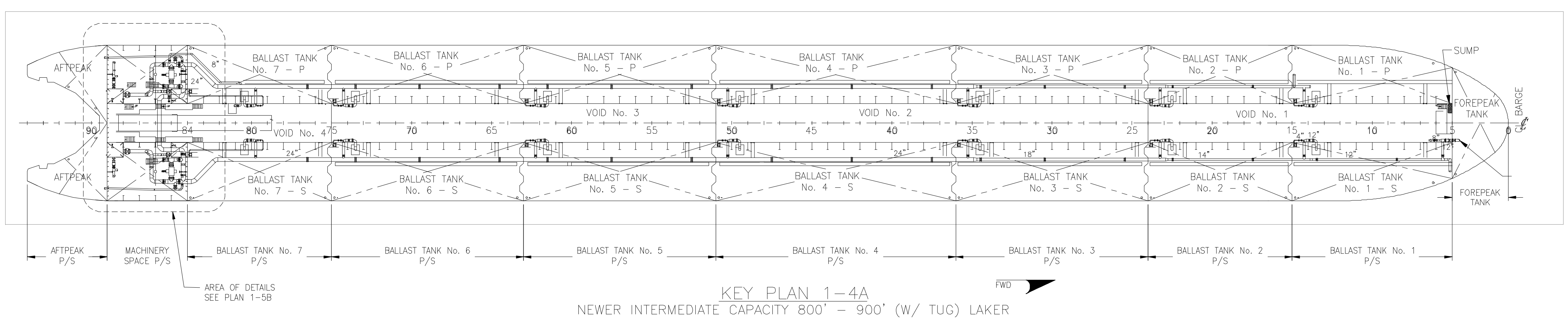


Figure D-1. Vessel Four, BWT System 1 (filter/UV BWT): general arrangement (1 of 4).

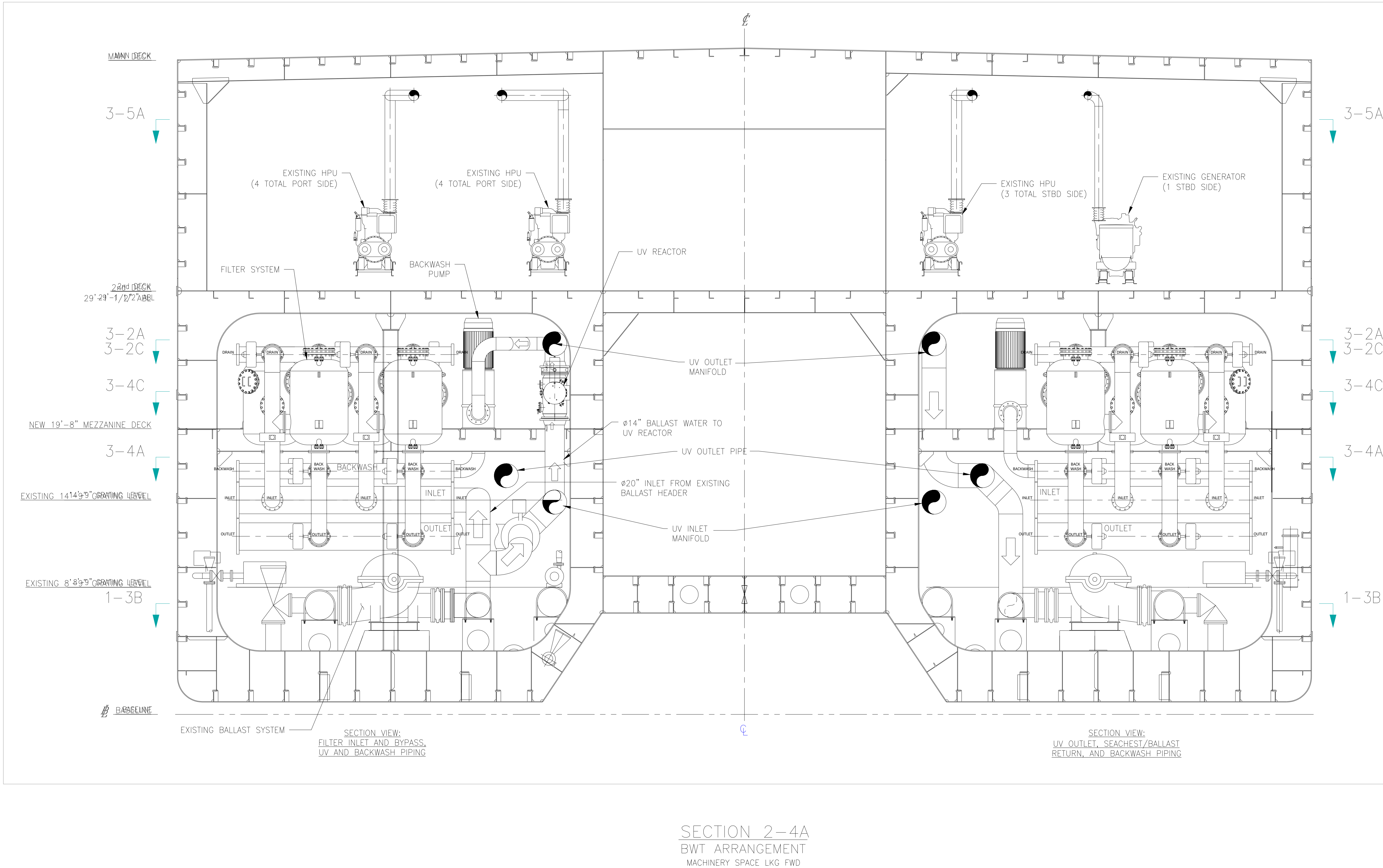


Figure D-1. Vessel Four, BWT System 1 (filter/UV BWT): general arrangement (2 of 4).

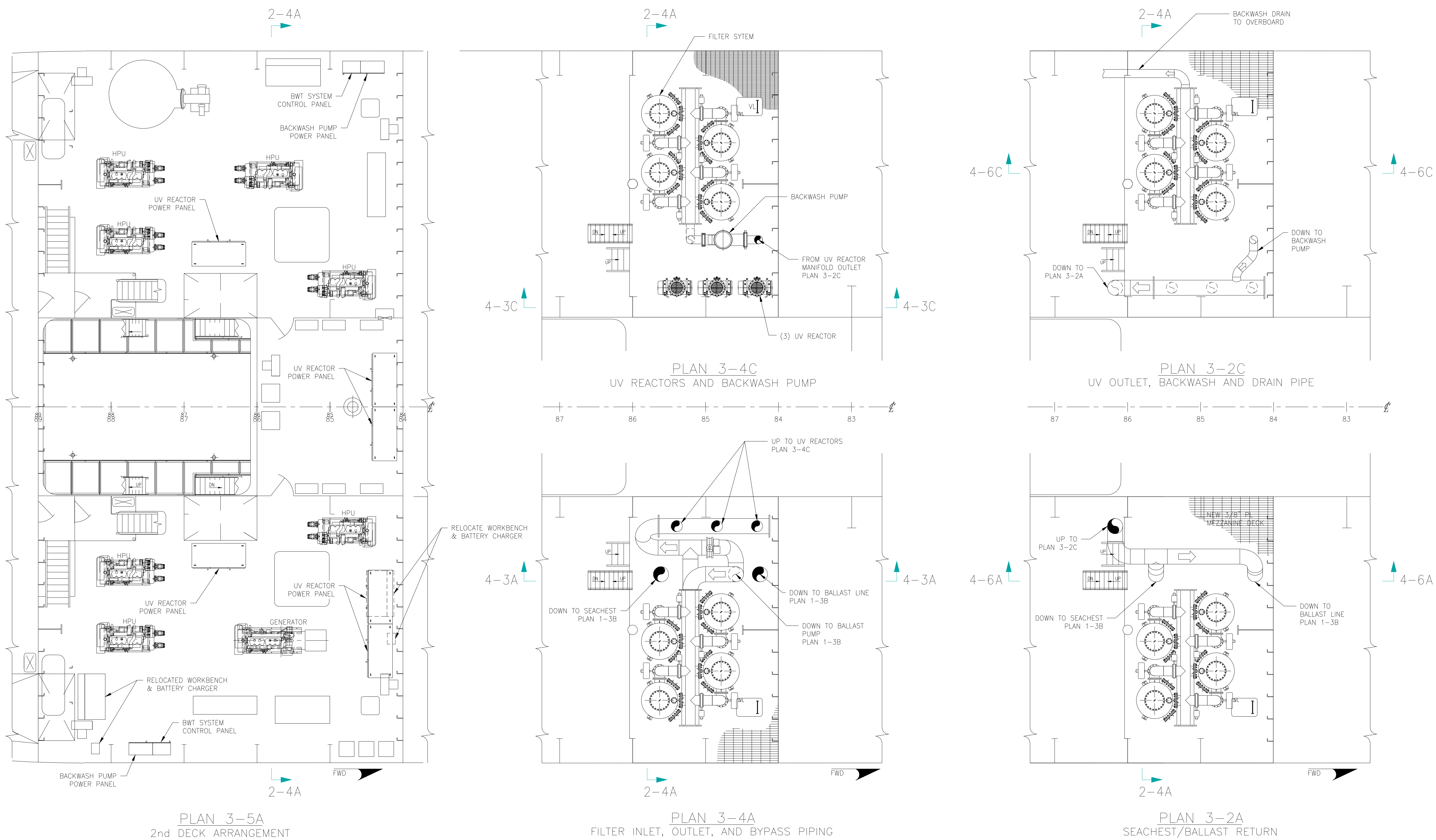


Figure D-1. Vessel Four, BWT System 1 (filter/UV BWT): general arrangement (3 of 4).

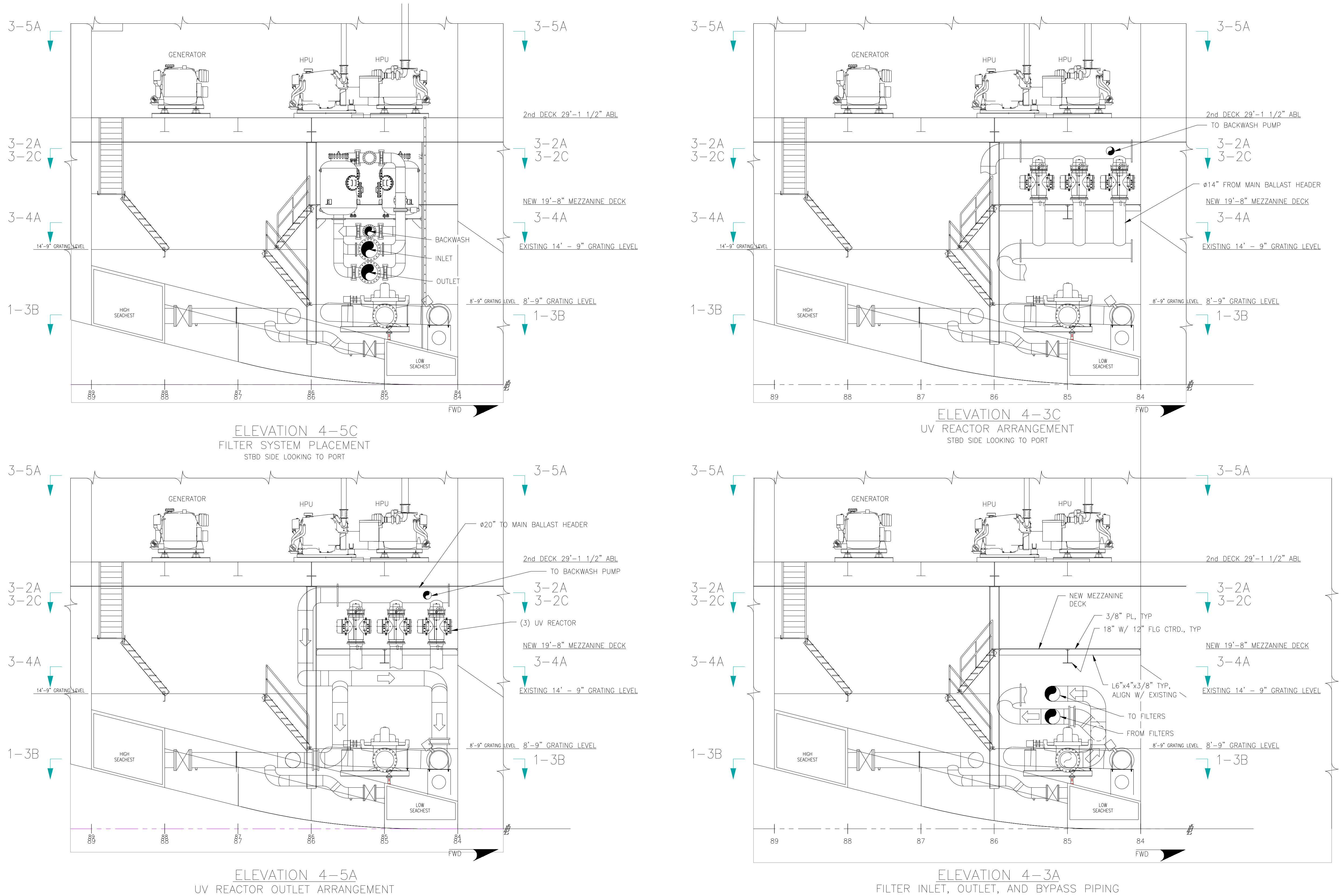


Figure D-1. Vessel Four, BWT System 1 (filter/UV BWT): general arrangement (4 of 4).

MATERIAL SCHEDULE

SERVICE	SIZE	PIPE	TAKEDOWN JOINTS			FITTINGS	VALVES	
			MATERIAL	GASKETS	BOLTING		BODY	TRIM
BALLAST WATER	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28	BUTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS

SYMBOLS LIST

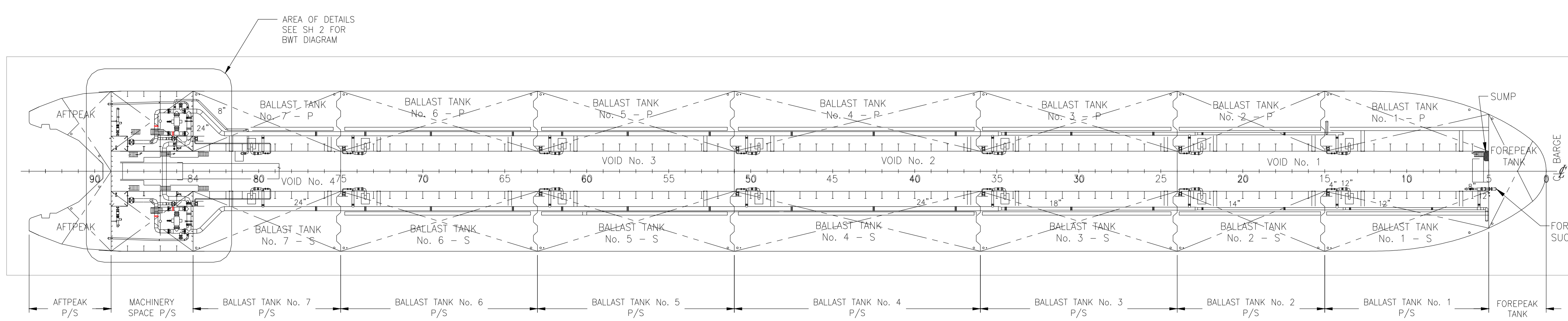
	NEW PIPE W/ FLOW DIRECTION
	EXISTING PIPE W/ FLOW DIRECTION
	BUTTERFLY VALVE REMOTELY OPERATED (ELEC THROTTLING) W/ CAPABILITY OF MANUAL OPERATION
	BUTTERFLY VALVE REMOTELY OPERATED (AIR OPEN OR CLOSE) W/ CAPABILITY OF MANUAL OPERATION
	BUTTERFLY VALVE
	GLOBE VALVE
	GATE VALVE
	BHD/DECK PENETRATION
	SWING CHECK VALVE
P	PRESSURE GAUGE
	DRESSER COUPLING W/ ANCHOR BOLTS
	CROSSING PIPES CONNECTED
	CROSSING PIPES NOT CONNECTED
	SUCTION BELLMOUTH
PV	PRIMING VALVE
	DECK PENETRATION

MAJOR EQUIPMENT LIST

QTY.	ITEM	MAKE	MODEL	CAPACITY	DRIVE/NOTES
4	BUTTERFLY VALVE	–	ø10"	–	–
4	SWING CHECK VALVE	–	ø10"	–	–
2	GATE VALVE	–	ø10"	–	–
12	BUTTERFLY VALVE	–	ø16"	–	–
2	BUTTERFLY VALVE	–	ø20"	–	PNEUMATIC

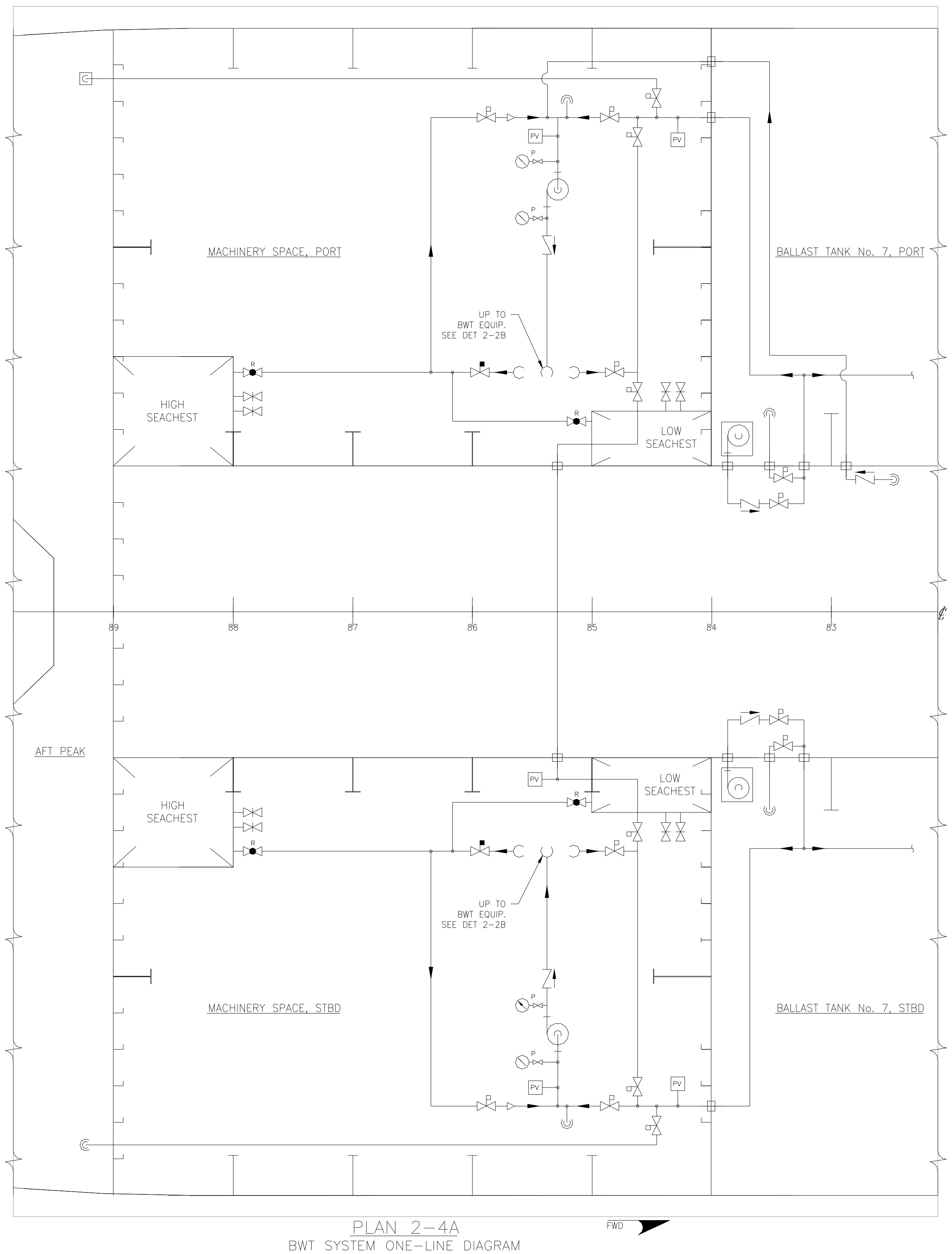
PUMP LIST

QTY.	SERVICE	TYPE	MODEL	CAPACITY	DRIVE
2	BACKWASH PUMP	CENTRIFUGAL	–	3,963 GPM AT 5 BAR	250 HP ELECTRIC MOTOR



KEY PLAN 1-4A
NEWER INTERMEDIATE CAPACITY 800' – 900' (W/ TUG) LAKER
TANK ARRANGEMENT

Figure D-2. Vessel Four, BWT System 1 (filter/UV BWT): piping diagram (1 of 2).



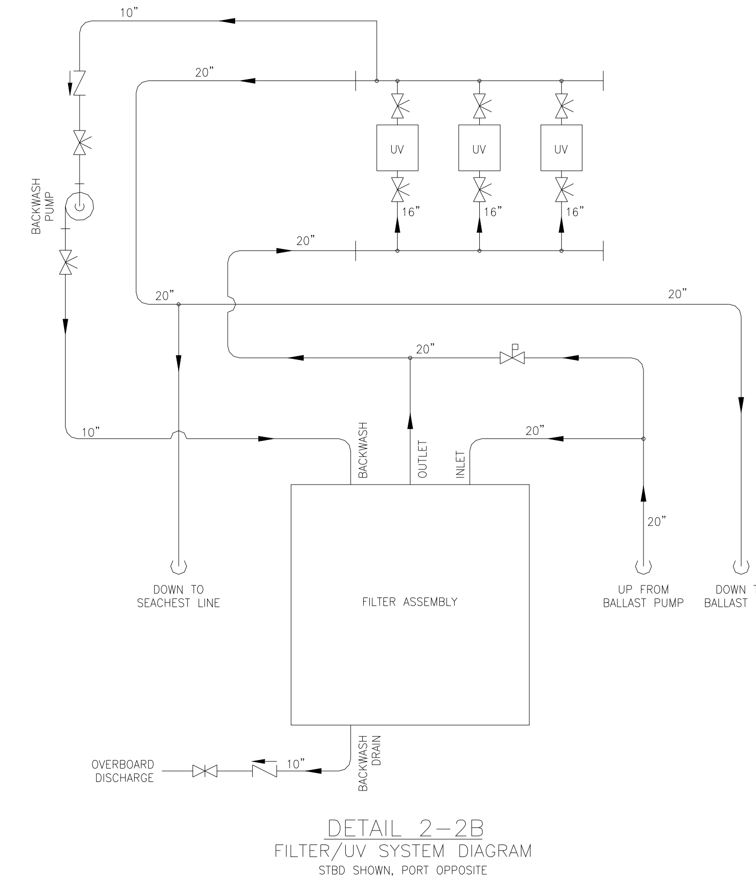


Figure D-2. Vessel Four, BWT System 1 (filter/UV BWT): piping diagram (2 of 2).

D.2 Vessel Four, BWT System 2: Ozone

D.2.1 Vessel Four, BWT System 2: Ventilation Calculation

The ozone BWT system is located in a single space. The system has a large air requirement to operate; see Table D-4.

Table D-4. Vessel Four, BWT System 2: ventilation requirements calculation.

Summary

This spreadsheet performs calculations to determine required ventilation for new BWT machinery space.

Air Requirements for Machinery

Item	*Formula*	*Value*	*Units*
Air compressor 1 inlet	Qc1 =	7,891.16	*cfm*
Total air requirement	Qt1 = Qc1	7,891.16	*cfm*
Extra air provided for adequate ventilation	Qt2 = 2 * Qt1	15,782.31	*cfm*
New ventilation required	**Qt = Qt2**	**15,782.31**	***cfm***
Ventilation per fan	**Qf = Qt**	**15,782.31**	***cfm***

Selected Fan

Make	*Model*	*Dimensions*		*Units*
Hartzell	A48---366DA---ST___4	Size	36.00	*in*
		Static Pressure	0.75	*in*
		Flow Rate	17,299.00	*cfm*
		Motor RPM	1,160.00	*rpm*
		Motor Power	4.10	*Hp*

D.2.2 Vessel Four, BWT System 2: Electrical Loads Analysis

The addition of the BWT increases the electrical load on the vessel. The existing electrical power for the vessel is 1,200 kW. The electrical power has to increase to 1,585 kW to accommodate the addition of the BWT; see Table D-5. The additional electrical power is supplied through a shore power connection. The shore power connection cannot run in parallel with the ship's generators. Instead, the entire extra load from the BWT system (937 kW) is supplied independent from the ship's service power. This extra power comes from the new shore power connection.

Table D-5. Vessel Four, BWT System 2: electrical load analysis for addition of BWT 2.

	#	power (kW)	total (kW)
Air Compressor	1	114	114
Ozone Generator	1	200	200
Chiller	1	252	252
Condenser Water Pump	1	2	2
Ozone Injector Pumps	2	75	150
Ventilation	1	2	2
		Total	**720**

D.2.3 Vessel Four, BWT System 2: Deadweight Analysis

The light ship weight of the vessel increases because of the addition of the BWT system, generator and electrical system installation, and ancillary system changes. The weight change decreases the cargo carrying capacity of the vessel. Table D-6 contains the weight change summary.

Table D-6. Vessel Four, BWT System 2: weight estimate.

	OZONE SYSTEM INSTALL WEIGHT ESTIMATE		
SWBS No.	Description	Qty.	Total Wt. (lbs)
	SUMMARY		
100	STRUCTURE		22,416
200	MACHINERY		83,972
300	ELECTRICAL		21,604
	OZONE SYSTEM WEIGHT		**127,991 (57.1 LT)**

D.2.4 Vessel Four, BWT System 2: Cost Estimate

The vessel will have to be modified for the installation of the BWT. Structural changes and existing system will have to be modified. The modification will require accesses to be cut and repaired. The summary cost is $6,330,609; see Table D-7.

D.2.5 Vessel Four, BWT System 2: System Installation Drawings

The vessel structure and mechanical system will be modified for the BWT systems. The general arrangement and structural changes are shown in Figure D-3. Piping modifications are shown in Figure D-4.

Table D-7. Vessel Four, BWT System 2: preliminary cost estimate summary - shipboard ozone.

SWBS No.	Item Description	Labor Hours	Material & Services @ Cost ($)	Subcontracts @ Cost ($)	Labor Cost @ $70/Hr	Material & Services w/17% Mark-up ($)	Subcontracts w/8% Mark-up ($)	Item Total Costs	Percent of Total Cost
000	Project Management & Admin	151	$206,388	$102,480	$10,584	$241,474	$--	$252,058	3.98%
100	Structure	3918	$41,009	$--	$274,273	$47,981	$--	$322,253	5.09%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	2113	$509,298	$--	$147,921	$595,878	$--	$743,799	11.75%
400	Electronics & IC Systems	150	$2,901	$--	$10,506	$3,394	$--	$13,900	0.22%
500	Auxiliary Systems	1826	$56,989	$2,628,938	$127,792	$66,677	$2,839,253	$3,033,721	47.92%
600	Outfitting	1828	$21,974	$--	$127,949	$25,710	$--	$153,659	2.43%
700	Mission Specific Equipment	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	108	$26,712	$470,400	$7,526	$31,253	$508,032	$546,811	8.64%
900	Shipyard Support Services	2374	$46,480	$71,680	$166,208	$54,382	$78,131	$298,721	4.72%
	Contingency @ 18%							**$965,686**	**15.25%**
	Based on Concept Design Level								
	Totals For All Items	**12468**	**$911,751**	**$3,273,498**	**$872,759**	**$1,066,748**	**$3,425,416**	**$6,330,609**	**100%**

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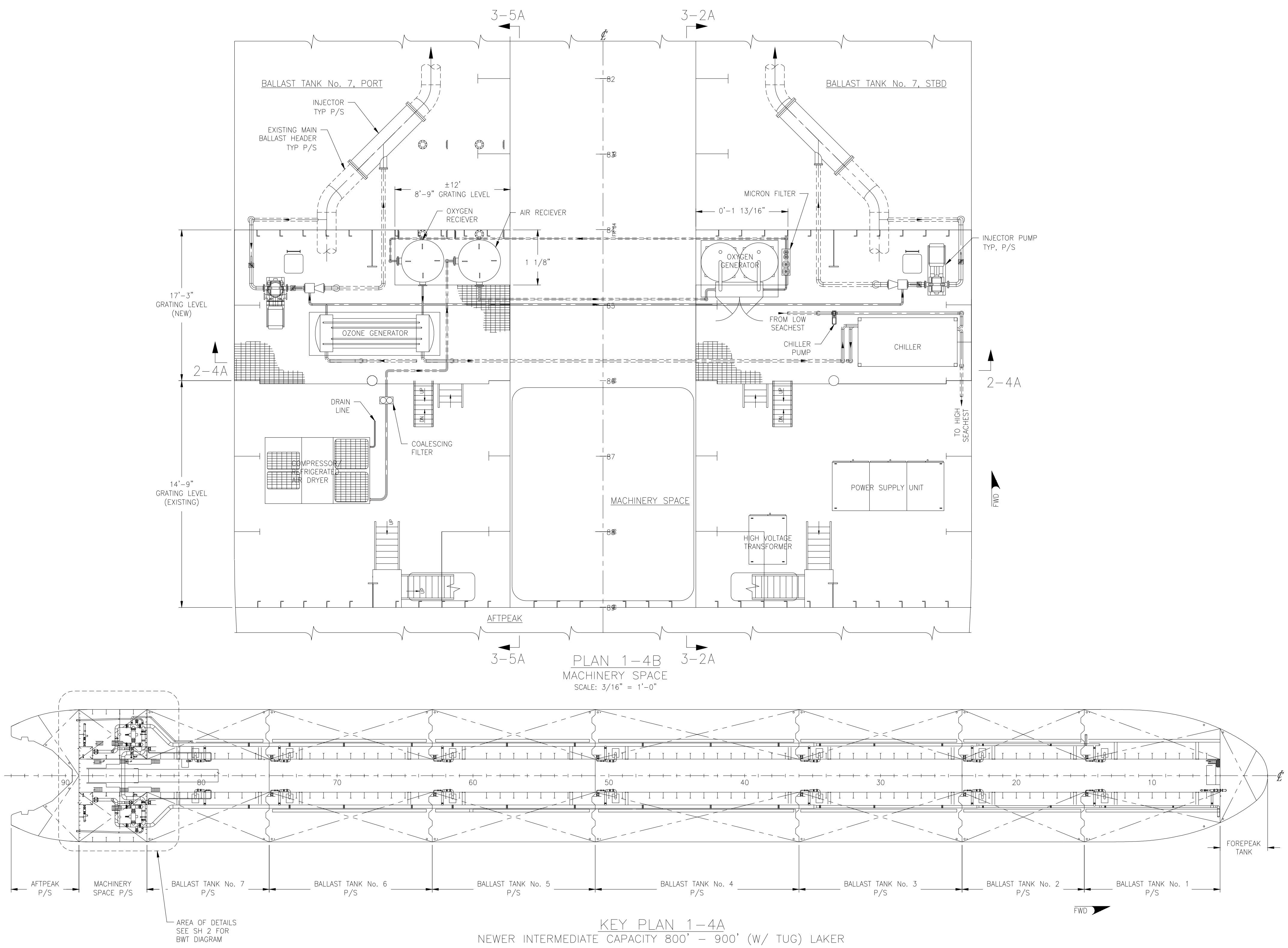


Figure D-3. Vessel Four, BWT System 2 (ozone BWT System): general arrangement (1 of 3).

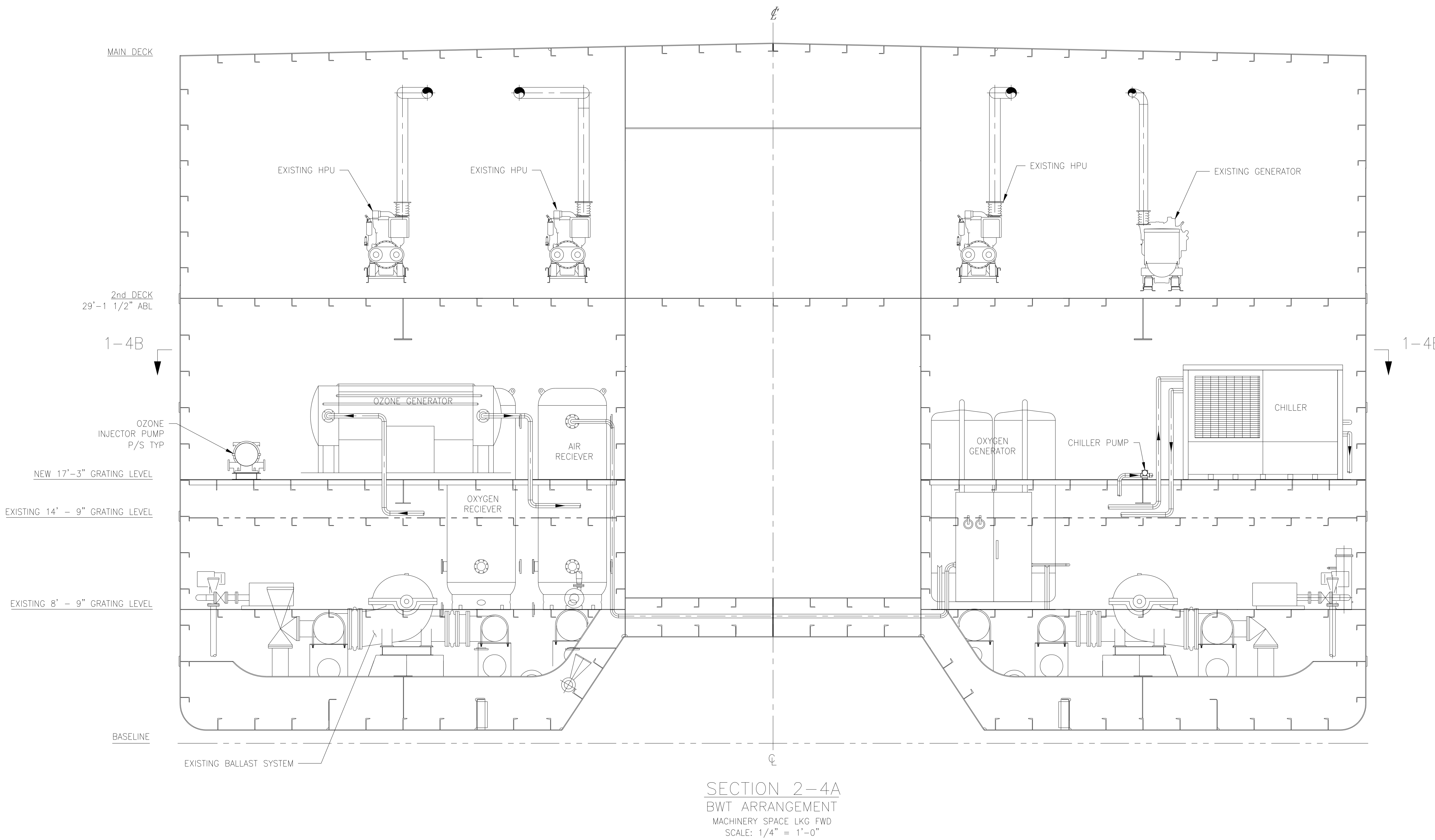
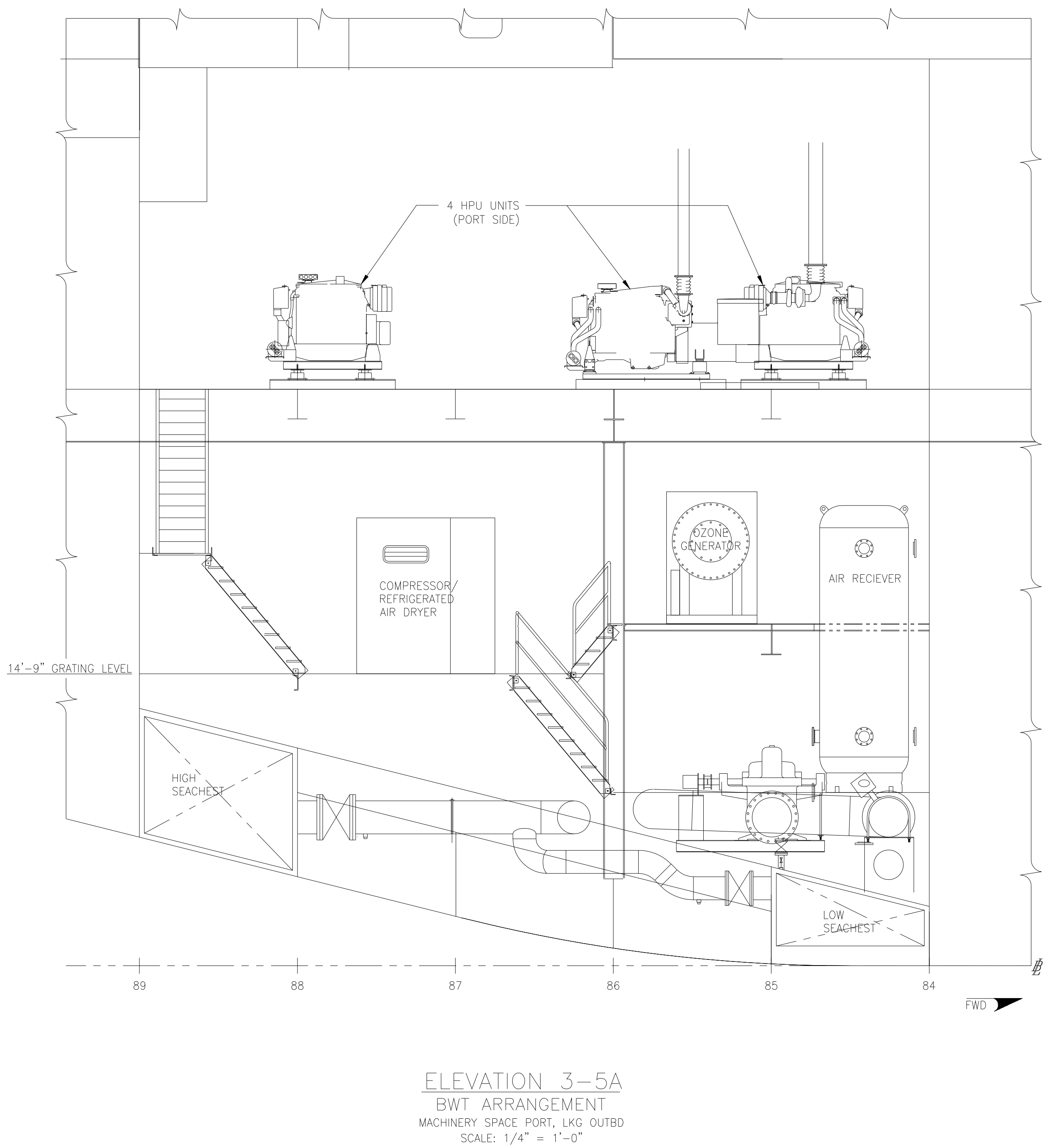


Figure D-3. Vessel Four, BWT System 2 (ozone BWT System): general arrangement (2 of 3).



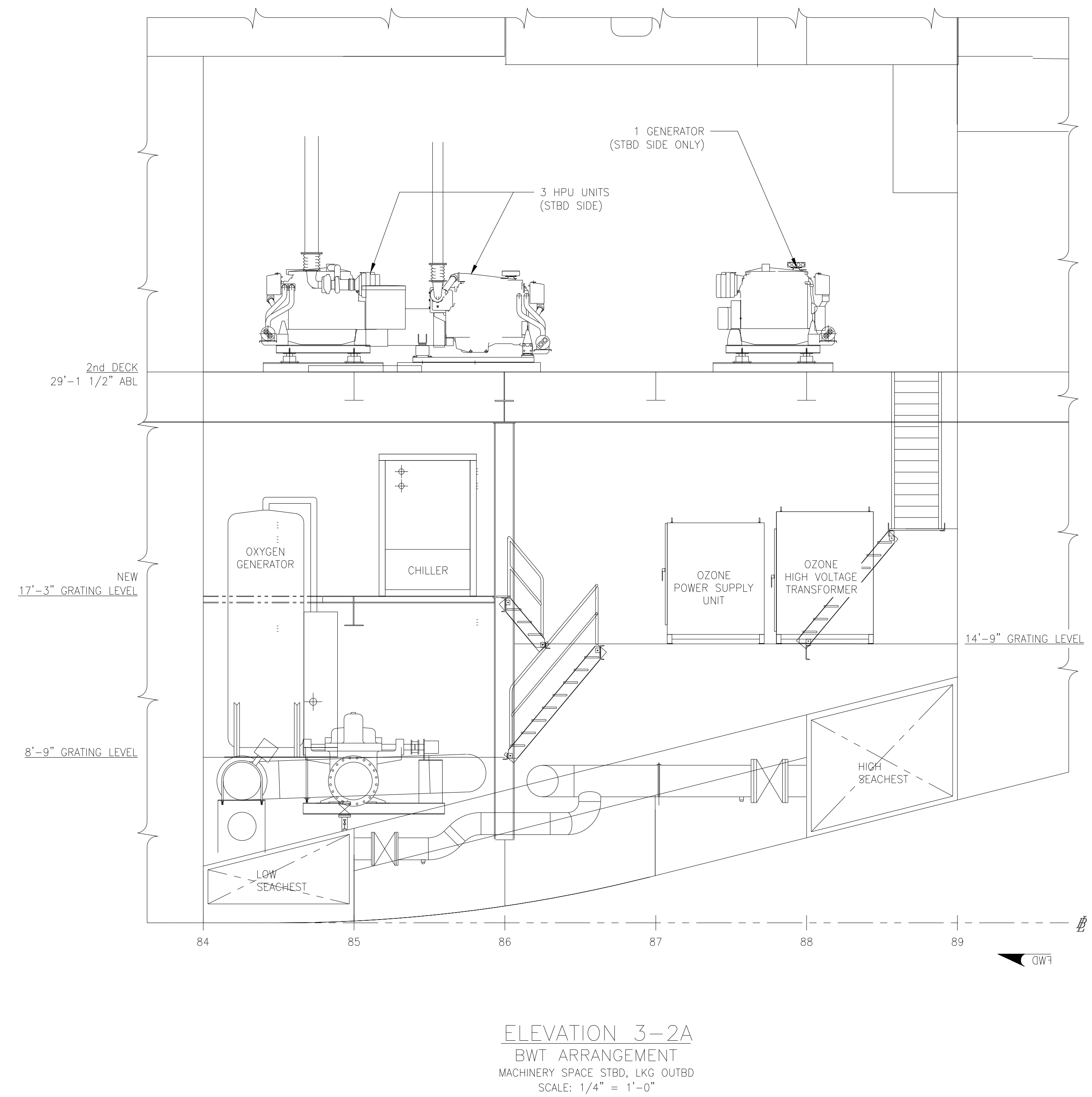


Figure D-3. Vessel Four, BWT System 2 (ozone BWT System): general arrangement (3 of 3).

SYMBOLS LIST

Symbol	Description
	NEW PIPE W/ FLOW DIRECTION
	EXISTING PIPE W/ FLOW DIRECTION
R-1	AIR RECIEVER
R-2	OXYGEN RECIEVER
TRO	TOTAL RESIDUAL OXIDANTS METER W/ ELECTRIC CABLE CONNECTION
PI	PRESSURE INDICATOR
	FLOW CONTROL VALVE
	PRESSURE REGULATOR
DP	DIFFERENTIAL PRESSURE INDICATOR
	CENTRIFUGAL PUMP
	OZONE INJECTOR
FM	.01 MICRON FILTER
FC	COALESCING FILTER
	CROSSING PIPES CONNECTED
	CROSSING PIPES NOT CONNECTED
	SEACHEST
	INCLUDED WITH BALLAST WATER TREATMENT SYSTEM
	OVERBOARD DISCHARGE
	GLOBE VALVE
	BHD/DECK PENETRATION
A	REMOTE ACTUATED DOUBLE ACTING BUTTERFLY VALVE (OPEN/CLOSE)
	GATE VALVE W/ REMOTE OPERATOR
PV	PRIMING VALVE
	SUCTION BELLMOUTH

MATERIAL SCHEDULE

SERVICE	SIZE	PIPE	TAKEDOWN JOINTS			FITTINGS	VALVES	
			MATERIAL	GASKETS	BOLTING		BODY	TRIM
BALLAST WATER	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28	BUTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS
COMPRESSED AIR	ALL	SCH 40 STAINLESS STEEL SEAMLESS ASTM A-312, GR 316L ANSI B16.10	150# FLANGE, SLIP-ON STAINLESS STEEL ASTM A-182, GR 316L ANSI B16.5	GARLOCK GYLON STYLE 3510 OR EQUAL	316 STAINLESS	SCH 40 STAINLESS STEEL, ASTM A-182 TYPE 316, ANSI B16.9	ALL TYPES, ASTM A351, GRADE CF8M, AISI TYPE 316 STAINLESS STEEL FLANGED 150#, ANSI B1.10 & B16.34	REMOVABLE SEATS. A316 STAINLESS STEEL OR MONEL DISK, STAINLESS STEEL STEM
COMPRESSED OXYGEN	ALL	SCH 40 STAINLESS STEEL SEAMLESS ASTM A-312, GR 316L ANSI B16.10	150# FLANGE, SLIP-ON STAINLESS STEEL ASTM A-182, GR 316L ANSI B16.5	--	316 STAINLESS	SCH 40 STAINLESS STEEL, ASTM A-182 TYPE 316, ANSI B16.9	ALL TYPES, ASTM A351, GRADE CF8M, AISI TYPE 316 STAINLESS STEEL FLANGED 150#, ANSI B1.10 & B16.34	REMOVABLE SEATS. A316 STAINLESS STEEL OR MONEL DISK, STAINLESS STEEL STEM
OZONE	ALL	SCH 40 STAINLESS STEEL SEAMLESS ASTM A-312, GR 316L ANSI B16.10	150# FLANGE, SLIP-ON STAINLESS STEEL ASTM A-182, GR 316L ANSI B16.5	GARLOCK GYLON STYLE 3510 OR EQUAL	316 STAINLESS	SCH 40 STAINLESS STEEL, ASTM A-182 TYPE 316, ANSI B16.9	ALL TYPES, ASTM A351, GRADE CF8M, AISI TYPE 316 STAINLESS STEEL FLANGED 150#, ANSI B1.10 & B16.34	REMOVABLE SEATS. A316 STAINLESS STEEL OR MONEL DISK, STAINLESS STEEL STEM

MAJOR EQUIPMENT LIST

QTY.	ITEM	MAKE	MODEL	CAPACITY	DRIVE/NOTES
1	AIR COMPRESSOR	ATLAS COPCO	GA160FF	928 SCFM @ 125 PSI	ELECTRIC
1	COALESCING FILTERS	–	–	928 SCFM @ 125 PSI	–
1	AIR RECEIVER	OGSI	AST-1550/OST-1550	204 CU FT	–
1	OXYGEN GENERATOR	OGSI	OG-4000	67 SCFM @ 45 PSI	ELECTRIC
1	OXYGEN RECEIVER	OGSI	AST-1550/OST-1550	204 CU FT	–
1	0.01 MICRON FILTER	–	–	67 SCFM @ 45 PSI	–
1	OZONE GENERATOR	ITT WEDECO	PDO 2500	131 SCFM @ 15 PSI	ELECTRIC
1	CHILLER	FILTRINE	POC-8000-860	630,000 BTU/HR	ELECTRIC
1	GATE VALVE	–	–	ø5"	–
1	CHECK VALVE	–	–	ø5"	–
1	CHECK VALVE	–	–	ø1 1/2"	–
1	BUTTERFLY VALVE	–	–	ø12"	ELECTRIC ACTUATOR

NOTE: QUANTITIES LISTED ARE FOR ENTIRE SHIP.

PUMP LIST

QTY.	SERVICE	TYPE	MODEL	CAPACITY	DRIVE
2	STRIPPING PUMP (EXISTING)	CENTRIFUGAL	–	3,000 GPM	–
4	MAIN BALLAST PUMP (EXISTING)	CENTRIFUGAL	ALLIS CHALMERS, MODEL WSDV	13,000 GPM	200 HP ELECTRIC MOTOR
2	OZONE INJECTION PUMP (NEW)	CENTRIFUGAL	GOULDS PUMPS, MODEL 3410 M 6x8-11	1,200 GPM AT 100 FT HEAD	50 HP ELECTRIC MOTOR
2	CHILLER CIRCULATING PUMP (NEW)	CENTRIFUGAL	GOULDS PUMPS, MODEL 2ST1H5B2	80 GPM AT 75 FT HEAD	3 HP ELECTRIC MOTOR

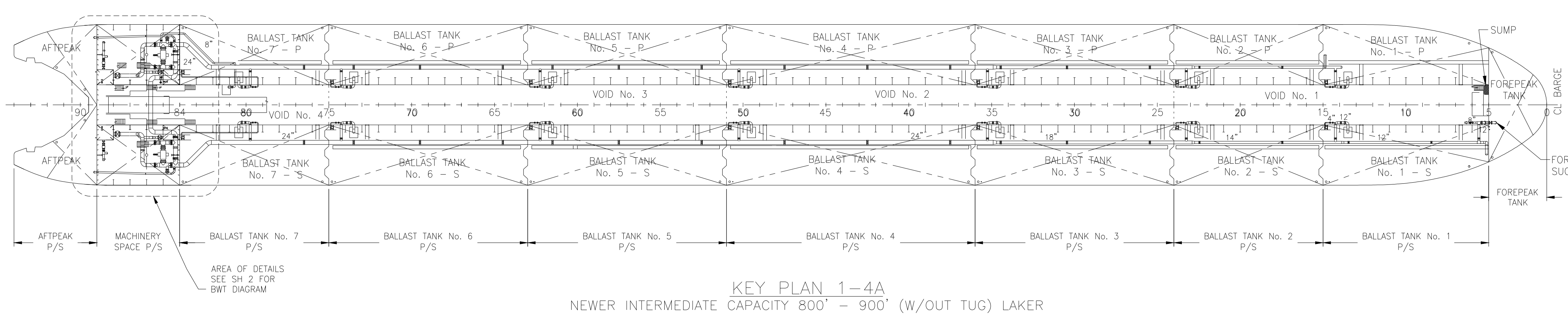


Figure D-4. Vessel Four, BWT System 2 (ozone BWT System): piping diagram (1 of 3).

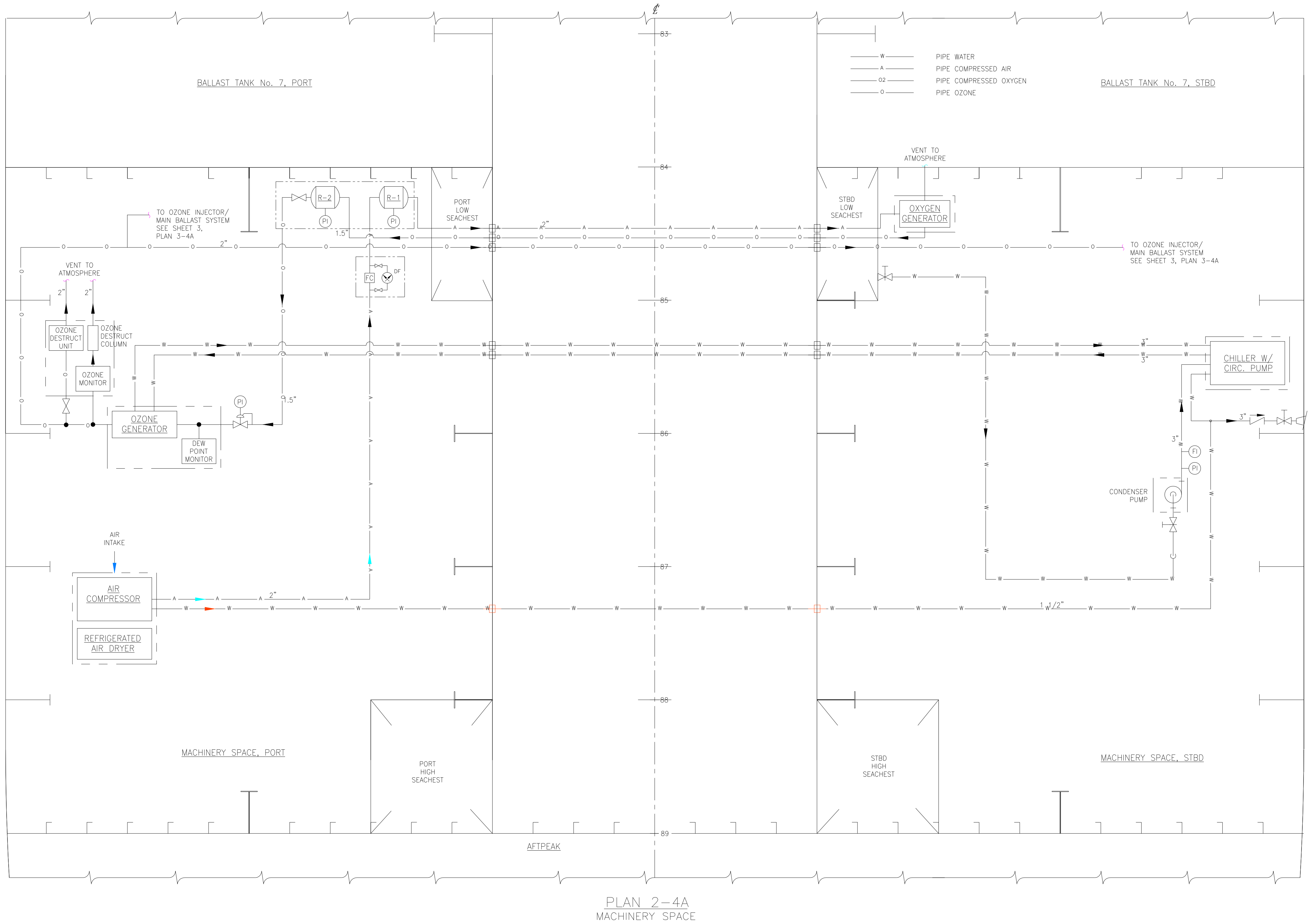


Figure D-4. Vessel Four, BWT System 2 (ozone BWT System): piping diagram (2 of 3).

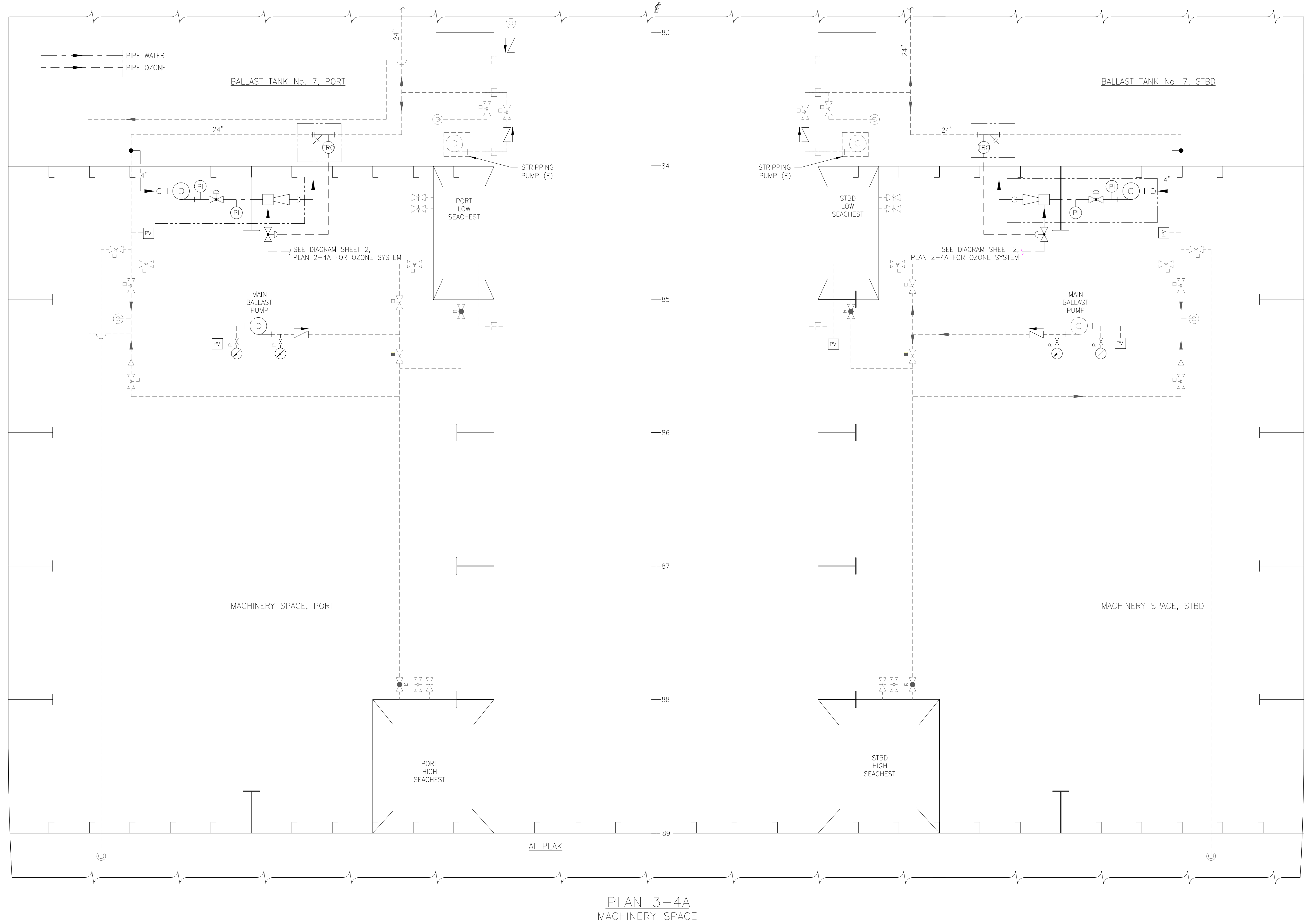


Figure D-4. Vessel Four, BWT System 2 (ozone BWT System): piping diagram (3 of 3).

APPENDIX E ALTERNATIVE BWM METHOD A – MUNICIPAL SEWAGE TREATMENT: SUPPORTING DOCUMENTS

E.1 Method A: Ship-to-Shore Connection

E.1.1 Method A: Ship-to-Shore Connection – Connection Hoses

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- 16" diameter connection hoses are readily available and affordable.
- 50' is the total elevation change from the manifold centerline to the vessel loading dock.
- All pressures are relative to an atmospheric pressure of 14.7 psi.
- Hose has sufficient strength to support its own weight and the weight of its contents, with minimal intermediate supports.

Connection hoses must withstand a negative pressure of 21.7 psi (50' head) without collapsing. Hose bend radius is approximately 60.0".

E.1.2 Method A: Ship-to-Shore Connection – Hose Handling Crane

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- Required hose maneuvers are accomplished by a telescoping crane with 40' radius.
- The crane moves each hose independently, one at a time.
- Specified hose is 16" diameter.
- Hose approximate bend radius is 60.0".
- Hose material weight equates to 33.12 pounds (lb)/foot (ft).
- Fluid is fresh water with average density of 62.428 lb/ft^3.
- Total hose length is 50.0'.

Table E-1 describes calculation of anticipated crane load. Specifications and design should be reexamined if this load calculation is no longer accurate and reasonable.

Crane is telescoping type, hose handling crane, pedestal mounted, maximum radius of 40.0' minimum radius of 28.0'. Crane must carry a minimum load of 6,100 lb. Include a minimum 80' of drum wire. Provide suitable hook and strap for hose handling. Crane is electrically powered. All hydraulic systems must be completely independent and require only electrical power.

Table E-1. Method A: calculation of anticipated crane load.

Load Calculation

Item	Unit Weight	Quantity	Units	Total
	lbs/unit	-	-	*lbs*
Hose material weight - 16" reinforced rubber hose	33.12	50.00	*ft*	1,656
Hose contents - fresh water - 16" internal diameter	87.17	50.00	*ft*	4,358
Hose coupler	40.00	2.00	*each*	80
Total				6,094
				(2.72 LT)

Crane must rotate on pedestal. Pedestal is 40' tall, permanently mounted on dock. Include access manholes and access ladders to reach crane machinery at top of pedestal. Provide suitable foundations for crane pedestal. Table E-2 describes the required range of motion for the crane hook location.

Table E-2. Method A: required range of motion for crane hook location.

Motion Range	Maximum	Minimum
Vertical range	40' above dock	5' above dock
Longitudinal range along dock	40' forward base	40' aft base
Transverse range out from dock	40' out	5' out

Provide suitable remote operator package for crane. Provide suitable corrosion protection and coating for all crane structure and machinery. Provide suitable lubrication oils and operating fluids for crane. Include spares and tools for one year of maintenance and operations.

E.1.3 Method A: Ship-to-Shore Connection – Loading Arms

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- 16" diameter loading arms are readily available.
- 50' is the total net elevation change from the manifold centerline to the vessel loading dock.
- All pressures are relative to an atmospheric pressure of 14.7 psi.
- The deck of the ship is always a minimum of 5' above the dock level.
- The deck of the ship is never more than a maximum of 40' above the dock level.
- The ship is positioned so that the longitudinal distance from the manifold connection to the loading arm is never more than 40' from the base of the loading arm.
- The ship is positioned so that the transverse distance from the manifold connection to the loading arm is never more than 40' from the base of the loading arm.

Loading arms must withstand a negative pressure of 21.7 psi (50' head) without collapsing. Fit loading arms with quick connection fittings. Loading arms are 16.0" diameter. Table E-3 describes the required range of motion.

Table E-3. Method A: required range of motion for loading arm.

Motion Range	Maximum	Minimum
Vertical range	40’ above dock	5’ above dock
Longitudinal range along dock	40’ forward base	40’ aft base
Transverse range out from dock	40’ out	5’ out

E.2 Method A: Shore-side Facilities

E.2.1 Method A: Shore-side Facilities – Transition Piping

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- Total piping distance from the shore-side facility to the storage facility is 2640’ (0.50 mile).
- Geographic elevation change from the shore-side facility to the storage facility is 30’.
- Anticipated flow rate is 52,000 gpm.
- Total flow rate is achieved through four pipes. This allows more flexibility to avoid conflict with existing utility systems.
- All pressures are relative to an atmospheric pressure of 14.7 psi.
- Pressure at end of transition piping has a head of 58’ (25.14 psi relative to atmosphere).

Pipe material can be either ductile iron, PVC pipe, or fusion-welded HDPE. Internal pipe diameter is 24” minimum. Piping is buried a sufficient distance below grade for proper pipe protection and compliance with any pertinent regulations.

E.2.2 Method A: Shore-side Facilities – Booster Pumps

E.2.2.1 Method A: Shore-side Facilities, Booster Pumps – Assumptions

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- Total required pump head is 144.2 feet (43.95 m.) – 62.5 psi (431 kPa).
- Total required flow rate for system is 52,000 gpm (11,810 m^3/hr).
- System is required to have backup redundancy.

Total required flow rate is 52,000 gpm (11,810 m^3/hr.), at a total pressure head of 62.5 psi (431 kPa). An array of four pumps in parallel are required, with one spare pump (5 pumps total). All pumps are identical. Individual pump requirements are 13,000 gpm (2,952.6 m^3/hr) at 62.5 psi (431 kPa); TACO pump model GT 45043-5008 or similar meets the pump requirements. Pump types are centrifugal, driven by 3-phase, 440 V, electric induction motors with variable frequency drives. Estimated required motor power is 439 kW. Inlet nominal diameter is 18” and outlet diameter is 16”. Pump motors shall have electronic control systems that all feed into a single user control panel.

The pump arrangement has a header on the inlet side and a second header on the outlet side. Both headers are square tubing, cross-section of 42.0” x 42.0”. Individual header branches are 24.0” pipe with a bolted flange connection. Each branch connection requires a butterfly valve. This header arrangement applies to both the inlet and outlet pump headers. Provide drain plugs in each header. Design and provide suitable foundations to mount each header (inlet above the dock, outlet below the dock.).

E.2.2.2 Method A: Shore-side Facilities, Booster Pumps – Design Calculations

Figure E-1 shows the calculations modeling for the pressure drop of piping from the dock side to the remote storage facility. Piping includes the head from the 58' tall storage tank. The total calculated pressure drop is 62.5 psi (431 kPa). The model and calculation was done using the DF DesignNet® version 4.18 by ABZ, Inc.

Figure E-2 shows the pump system curve for the proposed booster pumps (Taco Pumps, Aug 19, 2011).

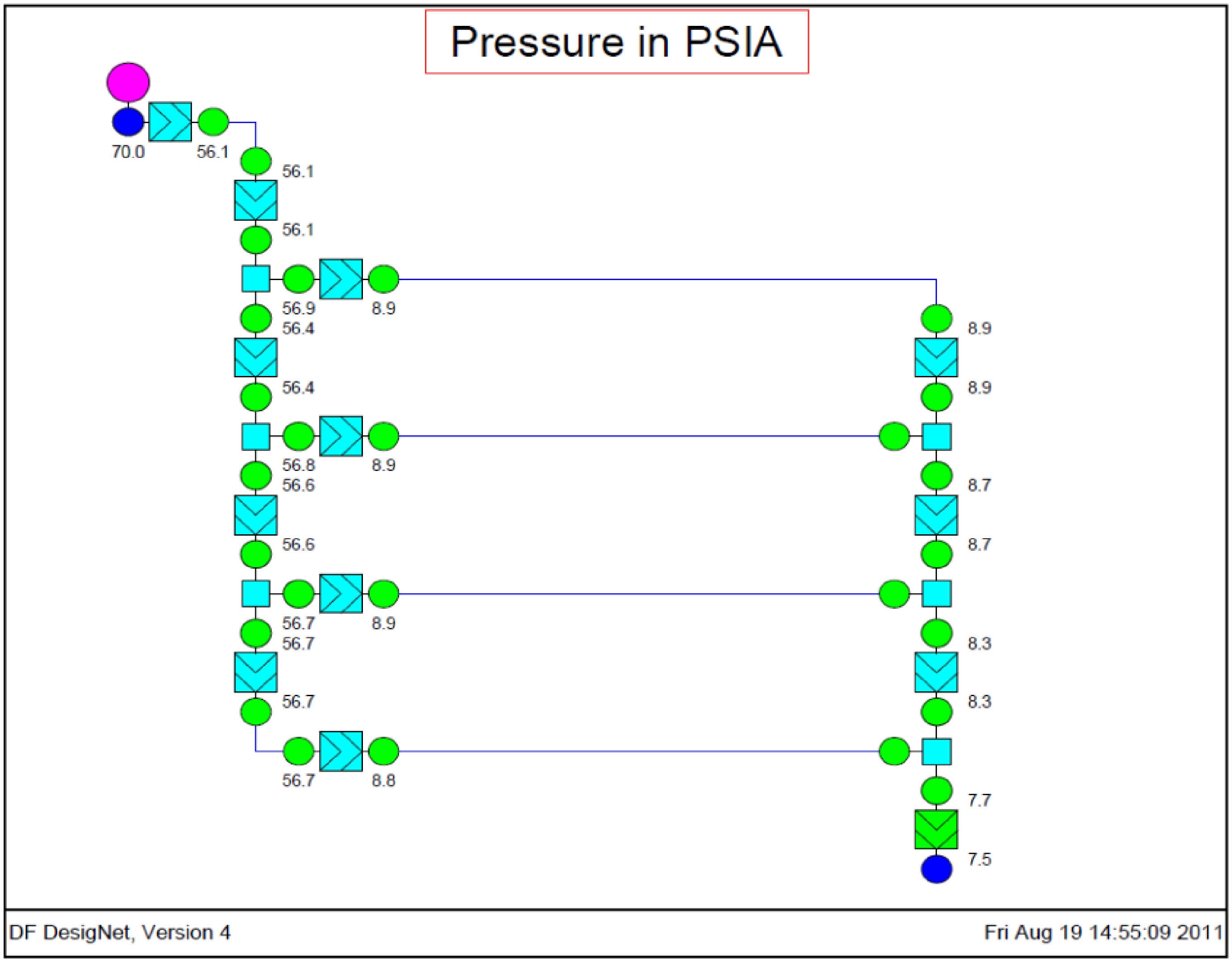


Figure E-1. Method A: calculations for transition piping to storage facility.

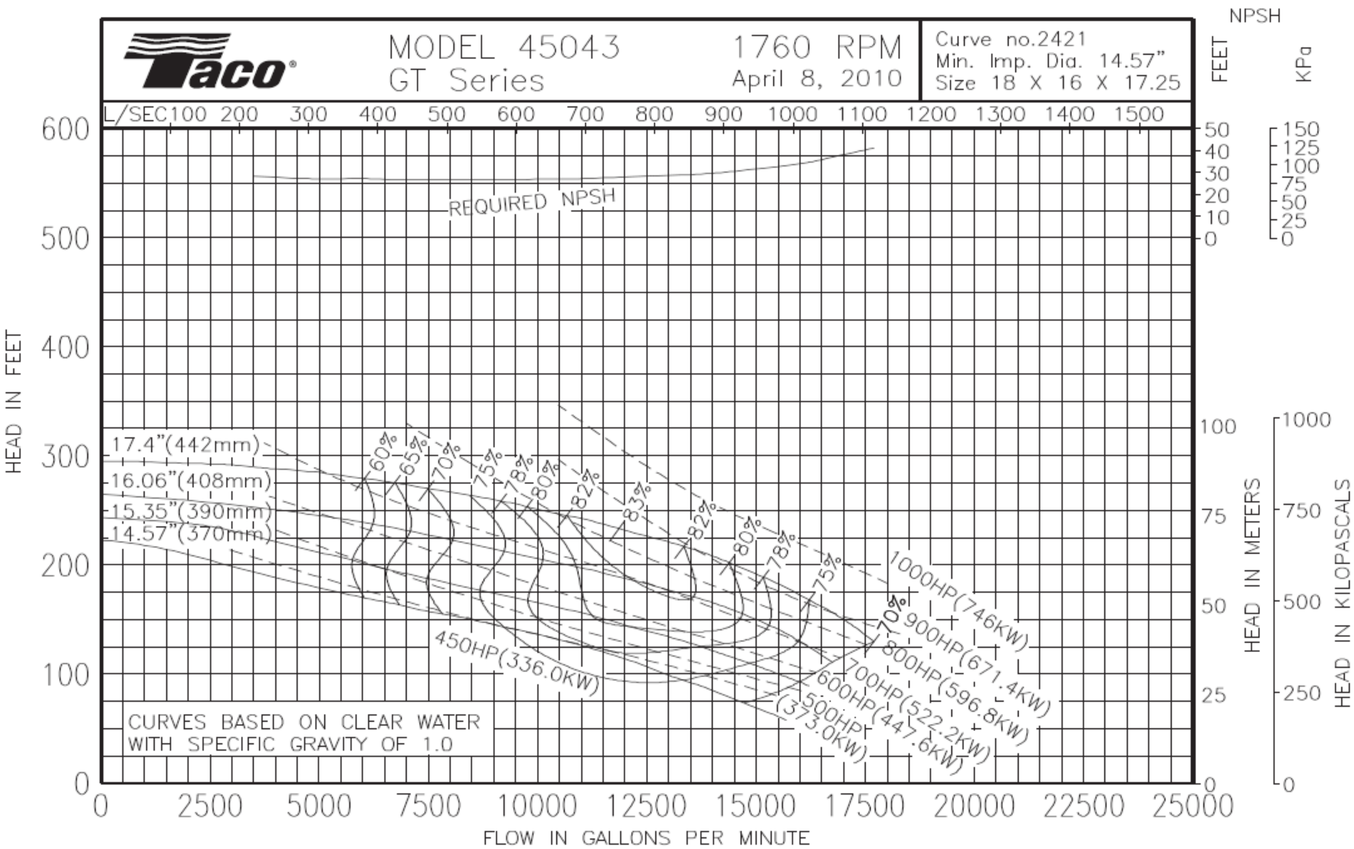


Figure E-2. Method A: pump system curve for booster pumps: Method A.

E.2.3 Method A: Shore-side Facilities – Storage Tanks

E.2.3.1 Method A: Shore-side Facilities, Storage Tanks – Assumptions

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- The storage facility is located at a remote site.
- Land property values at the remote site are significantly cheaper than property values near the water side, where the vessel loading terminal is located.
- The site chosen for the remote storage facility has ample space available to arrange the storage tanks in the most economical and optimum configuration.
- For port operations, a worst-case scenario is assumed where one Large 1000' Laker Class vessel arrives and discharges ballast. Twelve hours after the first vessel arrives, a second Large 1000' Laker Class vessel arrives and does the same. No further Large 1000' Laker Class vessels arrive after the second vessel. The ballast storage system is sized to sustain this rate of port activity.

E.2.3.2 Method A: Shore-side Facilities, Storage Tanks – Description

The ballast storage system requires 13 storage tanks. Each tank must have a storage capacity of 2,816,393 gal (10,661 m^3). Total storage capacity must be 36,613,108 gal (138,596 m^3).

Tanks must be cylindrical shaped. Tanks are designed similar to Superior Tanks model 92' 1-3/16" x 24' 1-1/2", but with the required individual storage capacity. The recommended internal dimensions for individual storage tank are 91.0' (27.7 m) inner diameter x 58.0' (17.7 m) height. Tanks are mild steel bolted plates. Bolted connections must be appropriately watertight. All steel surfaces, internal and external, must be coated for protection against corrosion. Provide a suitable foundation for storage tanks. Secure and anchor storage tanks to withstand all anticipated weather for the site, without damage to the tank. Assumed weather must include a 600-year storm.

Each tank must be vented. There should be access stairways to reach the top of tank and access holes at the top of the tank for tank maintenance. A permanent ladder should be installed inside the tank for personnel access. A 24.0" inner diameter pipe should be installed at the center of the tank floor. A 24.0" gate valve with electronic motor should be installed in the pipe at the tank. All connections will be bolted flange or welded.

The tank pipe connection must feed into a pipe distribution system. Four main transition pipes carry the ballast water into the storage facility. Ballast water from those pipes must be capable of routing to any individual tank or any combination of one to 3 storage tanks simultaneously. Pipe material can be either ductile iron, PVC pipe, or fusion-welded HDPE.

The distribution system must also be capable of draining any individual tank or any combination of one to three storage tanks simultaneously. Pipe material can be ductile iron, PVC pipe, or fusion-welded HDPE. The drainage must feed into the sewage system outlet. This drainage must occur at the same time that incoming ballast water flows into other storage tanks. Mixing of the inflow and outflow ballast water is permitted. The inflow ballast water must not pressurize the outflow ballast water in excess of a head of 58.0'.

Ensure pressure loss from all distribution piping and fittings does not exceed a pressure drop of 6.0 psi. (41.4 kPa). All valves are butterfly type with electronic motor controls. All motors must run by a central computer control system. The system must be capable of local or remote operation. Provide an electronic link to a monitoring station back at the shore-side facility. Provide all wiring and electric distribution network to power automated tank lighting; distribution system motors and distribution system controls.

E.2.3.3 Method A: Shore-side Facilities, Storage Tanks – Design Calculations

Table E-4 estimates required storage capacity, based on the assumptions already detailed.

E.2.4 Method A: Shore-side Facilities – Outlet to Municipal Sewer

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- Sewage system can accept ballast water at a rate of 3,250 gpm (738 m^3/hr).
- Sewage treatment facility has the capacity to accept this ballast water in addition to normal sewage and storm drain water.
- Sewage treatment facility possesses the necessary machinery and techniques to sterilize ballast water in accordance with the requirements of IMO BWT regulations (Marine Environmental Protection Committee, IMO, October 2008).

Table E-4. Method A: storage tank capacity calculation.

Summary

This spreadsheet estimated the required capacity of the ballast storage facility.

Total Ballast Capacity

Largest vessel		1000 foot class			
Largest vessel ballast capacity	V1 =	16,425,462	*gal*	62,177	m^3
Ballast discharge time	T1 =	6.62	*hr*	6.62	*hr*
Assume 24 hour period between vessels docking					
Period between docking	T2 =	12.00	*hr*	12.00	*hr*
Sewage system metering rate	Rs =	195,000	*gal/hr*	738	m^3/hr
Time to empty ballast into sewage system	T3 = V1 / Rs	84.23	*hr*	84.23	*hr*
Assume a worst case scenario of one 1000 foot class vessel docking and a second 1000 foot class vessel docks after 12 hours.					
Ballast still stored after 12 hour period	V2 = V1 - Rs * T2	14,085,462	*gal*	53,319	m^3
Safety factor	SF =	1.20	-	1.20	-
Total ballast storage capacity needed	**V3 = SF * (V2 + V1)**	**36,613,108**	***gal***	**138,596**	$\mathbf{m^3}$
Total time to empty storage tanks	**T4 = V3 / Rs**	**187.76**	***hr***	**187.76**	***hr***

Individual Tank Size

The ballast water will be stored in multiple tanks. A suitable minimum tank size must be determined.

Smallest vessel ballast capacity	V4 =	3,040,988	*gal*	11,511	m^3
Total storage capacity	V3 =	36,613,108	*gal*	138,596	m^3
Number of storage tanks	N = V3 / V4	12.04	-	12.04	-
Number of tanks (rounded up)	N =	13	-	13.00	-
Final volume of individual	V = V3 / N	2,816,393	*gal*	10,661	m^3
		376,497	ft^3		
Ratio of height to diameter (assumed)	R =	1.57	-	1.57	-
Individual tank diameter	$d = \left(\frac{4RV}{\pi}\right)^{1/3}$	91	*ft*	27.73	*m*
Individual tank height	h = d / R	58	*ft*	17.65	*m*

- Sewage system infrastructure has a pipeline within 50' (15.2 m) of the ballast storage facility that can accept the ballast water at a flow rate of 3,250 gpm (738 m^3/hr).
- All pipes for the distribution network of the ballast storage facility converge to single outlet for the sewage system.
- The same level of redundancy installed in the rest of the ballast treatment system is maintained in the sewage treatment pumps.
- Outlet to sewage system requires a vertical elevation change of 20.0' (6.10 m).

All pipes for the distribution network of the ballast storage facility converge into a single outlet for the sewage system. Pipe material can be either ductile iron, PVC pipe, or fusion-welded HDPE. At this outlet, the pipes split into two parallel pumps. Just before the inlet to each pump, install a manual operated butterfly valve and a digital flow meter. The flow meter should provide sensor data to the control system for the ballast storage facility. At the outlet to the pump, install a manually operated butterfly valve. Provide bolted flange connections. Design system with the capability to remove one pump for maintenance without stopping system operation.

- Pumps must have a flow capacity of 3,250 gpm (738 m^3/hr) at a differential pressure of 8.70 psi (60.0 kPa). Goulds Pumps model 3408A or similar is recommended. Pumps should be an identical model. Minimum required efficiency for each pump is 75 percent. Each pump is driven by a 23.5 hp (17.5 kW) electric motor. Motor will be a 3-phase, 240 V, induction type with a variable frequency drive. Variable frequency drive is controlled by the control system for the ballast treatment facility. Drive is adjusted to maintain a constant flow rate of 3,250 gpm (738 m^3/hr). Only one pump is needed to maintain this flow rate. The second pump acts as a backup.

Figure E-3 shows the pressure drop for the sewage outlet pumps under the assumed conditions previously stated. The diagram reflects that only one pump is active.

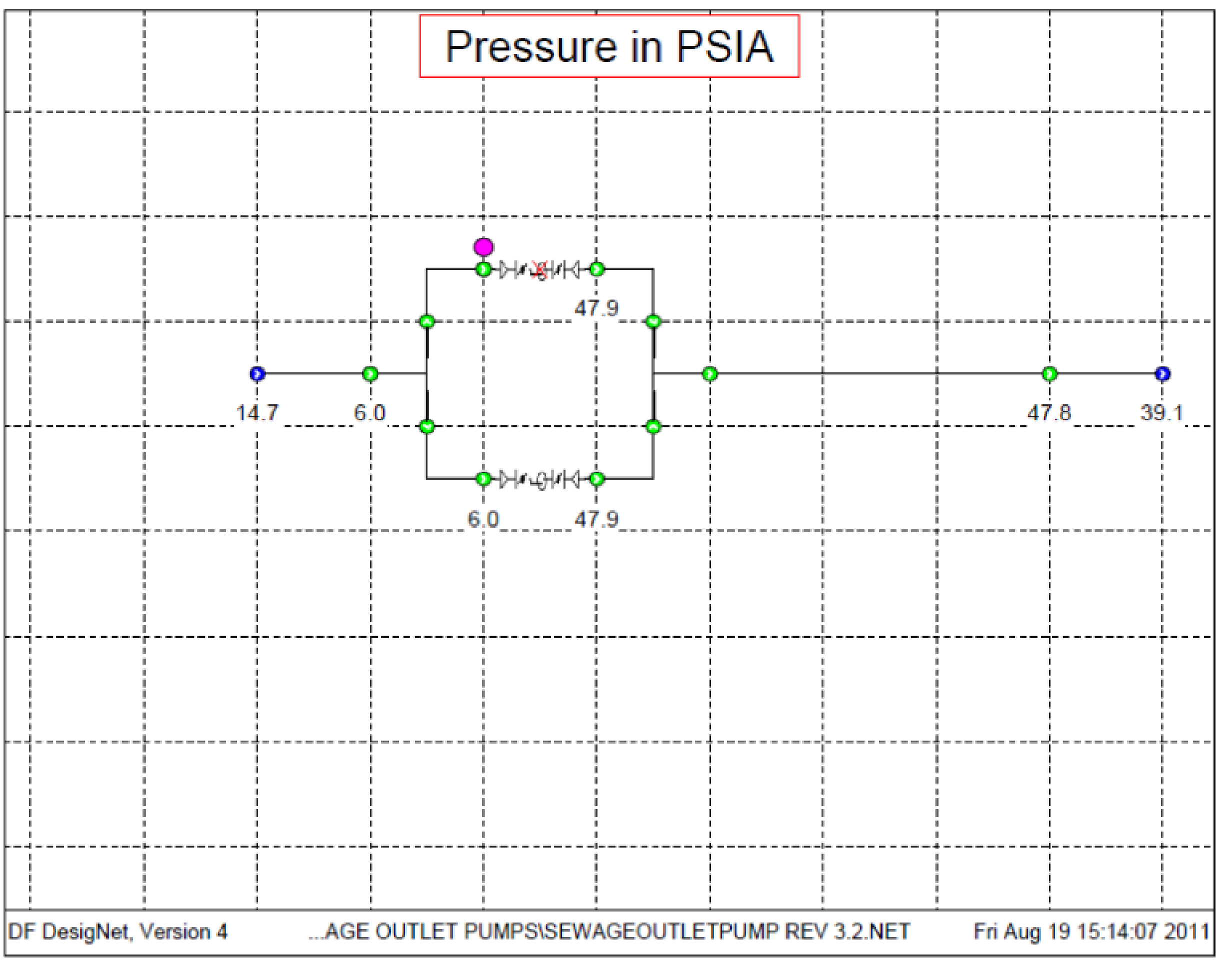


Figure E-3. Method A: pressure drop calculation for sewage outlet pumps.

The pump curve is shown in Figure E-4 (Goulds Pumps, August 19, 2011).

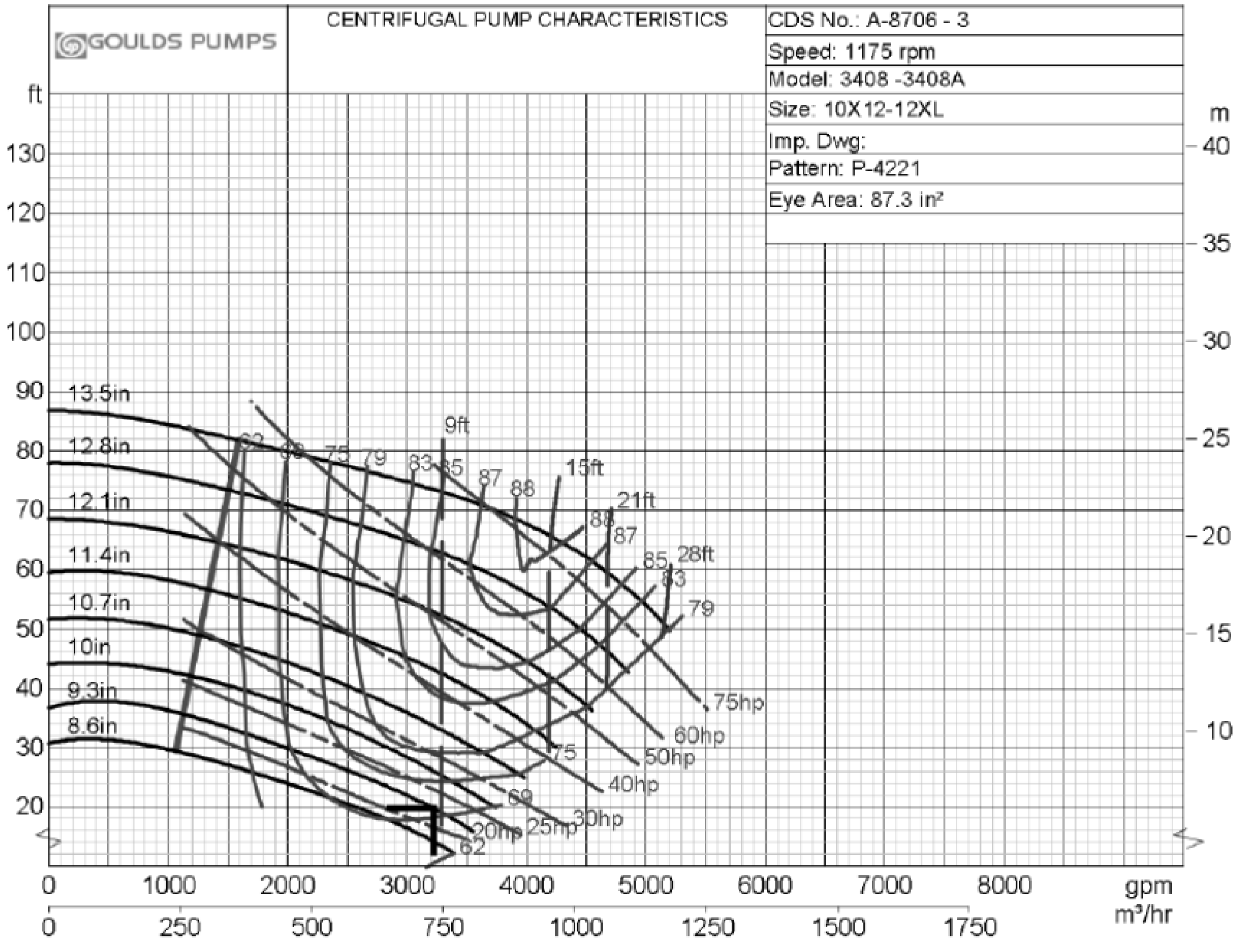


Figure E-4. Method A: pump system curve for outlet meter pumps.

E.2.5 Method A: Shore-side Facilities – Support Infrastructure

E.2.5.1 Method A: Shore-side Facilities, Support Infrastructure – Assumptions

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- Ballast storage facility operates autonomously with only occasional visits from workers for system maintenance.
- Facilities at loading dock area staffed by at least two full-time personnel to handle connections with vessels and monitor ballast water transfer.

E.2.5.2 Method A: Shore-side Facilities, Support Infrastructure – Ballast Storage Facility Description

The ballast storage facility requires basic support infrastructure plus a few minor facilities. Provide a fenced perimeter around ballast storage facility. Provide paved roadway access to the storage facility from the nearest public road. Obtain all necessary permits. Inside the storage facility, provide paved roads for access by a maintenance truck. Roads should lead to all ballast storage tanks and all other critical areas of the ballast storage facility.

Provide main electric supply from the local electric utility. Calculate anticipated power factor of the system predominant operating conditions. If calculated power factor is below 80 percent, provide suitable compensation (inductors or capacitors as necessary) to raise power factor up to 96 percent.

Provide automated control system for all motors and pumps within the ballast storage facility. Control system must have local user interface and remote user interface at the vessel loading dock. Control system must provide warnings (audible and visible) for system failure or power failure, including failure of the user interface. Design control system with default fail-safe actions in the event of system failure. Install main control system components at ballast storage facility. Install remote user interface at vessel loading dock. Provide linkage between two sites.

Install telephone communications system at ballast storage facility. This requirement may be waived if cell phone coverage at ballast storage facility is acceptable.

Provide a prefabricated metal building to house a control system and minor maintenance facilities. Building is prefabricated type, self-supported, and mounted on a cement foundation. Building will be of type manufactured by Allied Steel Buildings or similar (Allied Steel Buildings, 2011). Building must be weather-tight, able to withstand all reasonable weather for the region, and secure against vandalism.

Building is divided into two major rooms. The first room contains the computer components for the facility control system. This room is also provisioned as a small office with desk, file cabinets, and other necessary furniture. The second room is a small walk-in storage closet that contains maintenance supplies and tools. The building does not need to be insulated, unless climate control is required for the control system equipment.

E.2.5.3 Method A: Shore-side Facilities, Support Infrastructure – Loading Dock Hose and Crane Description

The support infrastructure for the dock-side facilities changes slightly, depending on whether a hose and crane, or a loading arm, is used for the connection. To ensure clarity of specification, separate descriptions of support infrastructure are given for each option.

The following specifications apply for the option of using hoses and cranes to connect to the ship. The dock-side support infrastructure requires facilities for personnel, hose storage, and an operations building to run all equipment.

Provide main electric supply from the local electric utility. Calculate anticipated power factor of the system predominant operating conditions. If calculated power factor is below 80 percent, provide suitable compensation (inductors or capacitors as necessary) to raise power factor up to 96 percent.

Install telephone communications system at dock-side ballast transfer facility. Communication system must include two separate lines and cabling routing throughout the operations office of the facility.

Provide a prefabricated metal building to house operations center, hose storage, and maintenance facilities. Building is prefabricated type, self-supported, and mounted on a cement foundation. Building is of type manufactured by Allied Steel Buildings or similar (Allied Steel Buildings, 2011). Building must be weather-tight, able to withstand all reasonable weather for the region, and secure against vandalism. Building is divided into three major rooms.

The first room contains the operations center for the ballast transfer operation. Operations room must contain a central computer console to monitor ballast transfer operations. This console must include the remote link to the control system for the ballast storage facility. Room must have adequate lighting and power receptacles for an office environment. Room must be insulated and have suitable heating machinery to maintain climate control. This room is also provisioned as an office with desk, file cabinets, and other necessary furniture.

The second room is a hose storage facility. This room includes two large access doors for vehicles to drive into this room and drive through back out. Install an overhead track crane in this room. Crane must have a 6 lt lifting capacity. Hoses are carried in on a flat-bed vehicle. Overhead crane lifts hoses off the vehicle and stores them in the room. Hoses may be stored on wall racks, or in floor bins.

The third room is a maintenance shop. This includes storage for maintenance supplies and tools. Provide suitable lighting and power receptacles for a workshop environment. Ensure room is insulated with suitable heating. Provide large access doors for vehicles to drive into this room. Provide an overhead track crane for hose handling. This room may be combined with the hose storage room.

E.2.5.4 Method A: Shore-side Facilities, Support Infrastructure – Loading Dock Loading Arm Description

The following specifications apply for the option of loading arms to connect to the ship. The dock-side support infrastructure requires facilities for personnel and an operations building to run all equipment.

Provide main electric supply from the local electric utility. Calculate anticipated power factor of the system predominant operating conditions. If calculated power factor is below 80 percent, provide suitable compensation (inductors or capacitors as necessary) to raise power factor up to 96 percent.

Install telephone communications system at dock-side ballast transfer facility. Communication system must include two separate lines and cabling routing throughout the operations office of the facility.

Provide a prefabricated metal building to house operations center and maintenance facilities. Building is prefabricated, self-supported, and mounted on a cement foundation. Building is of a type manufactured by Allied Steel Buildings or similar (Allied Steel Buildings, 2011). Building must be weather-tight, able to withstand all reasonable weather for the region, and secure against vandalism. Building is divided into two major rooms.

The first room contains the operations center for the ballast transfer operation. Operations room must contain a central computer console to monitor ballast transfer operations. This console must include the remote link to the control system for the ballast storage facility. Room must have adequate lighting and power receptacles for an office environment. Room must be insulated and have suitable heating machinery to maintain climate control. This room is also provisioned as an office with desk, file cabinets, and other necessary furniture.

The second room is a maintenance shop. This includes storage for maintenance supplies and tools. Provide suitable lighting and power receptacles for a workshop environment. Ensure room is insulated with suitable heating. Provide large access doors for vehicles to drive into this room.

E.3 Method A: Cost Estimates

E.3.1 Method A: Installation Cost Estimate

Table E-5 through Table E-9 summarize installation cost estimates for the municipal sewage treatment system. Cost estimates include modifications to vessels, installation of shore connection equipment, installation of the BWTF, and any support infrastructure (Regents of the University of Minnesota, 2011).

Table E-5. Method A: Vessel One, Option 1 – installation cost estimate.

Preliminary Cost Estimate Summary: Shore-side Discharge Option No. 1 (Cranes & Hoses)									
SWBS No.	Item Description	Labor Hours	Material & Services @ Cost ($)	Subcontracts @ Cost ($)	Labor Cost @$70/Hr	Material & Services w/17% Mark-up ($)	Subcontracts w/8% Mark-up ($)	Item Total Costs	Percent of Total Cost
000	Project Management & Admin	55	$114,886	$--	$3,842	$134,417	$--	$138,259	5.38%
100	Structure	804	$6,973	$--	$56,285	$8,159	$--	$64,444	2.51%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	0	$--	$--	$--	$--	$--	$--	0.00%
400	Electronics & IC Systems	0	$--	$--	$--	$--	$--	$--	0.00%
500	Auxiliary Systems	2129	$47,137	$--	$149,018	$55,151	$--	$204,169	7.95%
600	Outfitting	591	$41,731	$--	$41,372	$48,826	$--	$90,197	3.51%
700	Shore-side Installation	3145	$129,437	$1,076,544	$220,150	$151,441	$1,162,668	$1,534,258	59.72%
800	Integration & Engineering	0	$58,800	$--	$--	$68,796	$--	$68,796	2.68%
900	Shipyard Support Services	672	$25,536	$--	$47,040	$29,877	$--	$76,917	2.99%
	Contingency @ 18%							**$391,867**	**15.25%**
	Based On Concept Design Level								
	Totals For All Items	**7396**	**$424,501**	**$1,076,544**	**$517,707**	**$496,666**	**$1,162,668**	**$2,568,907**	**100%**

Table E-6. Method A: Vessel One, Option 2 – installation cost estimate.

Preliminary Cost Estimate Summary: Shore-side Discharge Option No. 2 (Using Loading Arms)									
SWBS No.	**Item Description**	**Labor Hours**	**Material & Services @ Cost ($)**	**Subcontracts @ Cost ($)**	**Labor Cost @$70/Hr**	**Material & Services w/17% Mark-up ($)**	**Subcontracts w/8% Mark-up ($)**	**Item Total Costs**	**Percent of Total Cost**
000	Project Management & Admin	55	$114,886	$--	$3,842	$134,417	$--	$138,259	4.00%
100	Structure	550	$4,778	$--	$38,477	$5,591	$--	$44,068	1.28%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	0	$--	$--	$--	$--	$--	$--	0.00%
400	Electronics & IC Systems	0	$--	$--	$--	$--	$--	$--	0.00%
500	Auxiliary Systems	2129	$47,137	$--	$149,018	$55,151	$--	$204,169	5.91%
600	Outfitting	591	$41,731	$--	$41,372	$48,826	$--	$90,197	2.61%
700	Shore-side Installation	2204	$47,677	$1,940,960	$154,294	$55,782	$2,096,237	$2,306,312	66.74%
800	Integration & Engineering	0	$58,800	$--	$--	$68,796	$--	$68,796	1.99%
900	Shipyard Support Services	672	$25,536	$--	$47,040	$29,877	$--	$76,917	2.23%
	Contingency @ 18% **Based On Concept Design Level**							**$527,169**	**15.25%**
	Totals For All Items	**6201**	**$340,545**	**$1,940,960**	**$434,043**	**$398,438**	**$2,096,237**	**$3,455,887**	**100%**

Table E-7. Method A: Vessel Two, Option 1 – installation cost estimate.

Preliminary Cost Estimate Summary: Shore-side Discharge Option No. 1 (Hoses & Cranes)									
SWBS No.	**Item Description**	**Labor Hours**	**Material & Services @ Cost ($)**	**Subcontracts @ Cost ($)**	**Labor Cost @$70/Hr**	**Material & Services w/17% Mark-up ($)**	**Subcontracts w/17% Mark-up ($)**	**Item Total Costs**	**Percent of Total Cost**
000	Project Management & Admin	157	$244,140	$--	$10,976	$285,644	$--	$296,620	9.73%
100	Structure	2284	$21,675	$--	$159,893	$25,359	$--	$185,252	6.08%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	0	$--	$--	$--	$--	$--	$--	0.00%
400	Electronics & IC Systems	242	$605	$--	$16,934	$708	$--	$17,642	0.58%
500	Auxiliary Systems	15787	$450,686	$--	$1,105,119	$527,303	$--	$1,632,422	53.56%
600	Outfitting	1400	$44,576	$--	$98,000	$52,154	$--	$150,154	4.93%
700	Shore-side Loading Arms & Piping	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	134	$111,776	$--	$9,408	$130,778	$--	$140,186	4.60%
900	Shipyard Support Services	1579	$42,627	$--	$110,544	$49,874	$--	$160,418	5.26%
	Contingency @ 18% **Based On Concept Design Level**							**$464,885**	**15.25%**
	Totals For All Items	**21584**	**$916,085**	**$--**	**$1,510,875**	**$1,071,819**	**$--**	**$3,047,579**	**100%**

Table E-8. Method A: Vessel Two, Option 2 – installation cost estimate.

Preliminary Cost Estimate Summary: Shore-side Discharge Option No 2, (Loading Arms)									
SWBS No.	**Item Description**	**Labor Hours**	**Material & Services @ Cost ($)**	**Subcontracts @ Cost ($)**	**Labor Cost @$70/Hr**	**Material & Services w/17% Mark-up ($)**	**Subcontracts w/17% Mark-up ($)**	**Item Total Costs**	**Percent of Total Cost**
000	Project Management & Admin	157	$244,140	$--	$10,976	$285,644	$--	$296,620	9.81%
100	Structure	2029	$19,479	$--	$142,018	$22,791	$--	$164,809	5.45%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	0	$--	$--	$--	$--	$--	$--	0.00%
400	Electronics & IC Systems	242	$605	$--	$16,934	$708	$--	$17,642	0.58%
500	Auxiliary Systems	15787	$450,686	$--	$1,105,119	$527,303	$--	$1,632,422	53.99%
600	Outfitting	1400	$44,576	$--	$98,000	$52,154	$--	$150,154	4.97%
700	Shore-side Loading Arms & Piping	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	134	$111,776	$--	$9,408	$130,778	$--	$140,186	4.64%
900	Shipyard Support Services	1579	$42,627	$--	$110,544	$49,874	$--	$160,418	5.31%
	Contingency @ 18% **Based On Concept Design Level**							**$461,205**	**15.25%**
	Totals For All Items	**21329**	**$913,890**	**$--**	**$1,493,000**	**$1,069,251**	**$--**	**$3,023,456**	**100%**

Table E-9. Method A: BWTF – installation cost estimate.

Cost Estimate Summary: Shore-side Facilities, Method A - Municipal Sewage									
SWBS No.	**Item Description**	**Labor Hours**	**Material & Services @ Cost ($)**	**Subcontracts @ Cost ($)**	**Labor Cost @$70/Hr**	**Material & Services w/17% Mark-up ($)**	**Subcontracts w/17% Mark-up ($)**	**Item Total Costs**	**Percent of Total Cost**
000	Project Management, Permits, etc.	2902	$577,920	$--	$203,123	$676,166	$--	$879,290	1.50%
100	Pier Structure, Foundations, Berms	851	$7,453,277	$--	$59,584	$8,720,334	$--	$8,779,918	15.01%
200	Shore Connection Equipment	0	$2,306,312	$--	$--	$2,698,385	$--	$2,698,385	4.61%
300	Power & Lighting System	0	$224,000	$--	$--	$262,080	$--	$262,080	0.45%
400	Controls, Monitoring, Alarms, etc.	179.2	$119,326	$--	$12,544	$139,611	$--	$152,155	0.26%
500	Manifolds & Piping Systems	0	$27,951,168	$--	$--	$32,702,867	$--	$32,702,867	55.91%
600	Buildings, Shelters, Fences	2038.4	$346,546	$--	$142,688	$405,459	$--	$548,147	0.94%
700	BWT System	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	89.6	$3,024,000	$--	$6,272	$3,538,080	$--	$3,544,352	6.06%
900	Equip't Rentals, Heavy Lift Cranes	0	$--	$--	$--	$--	$--	$--	0.00%
	Contingency @ 18% **Based On Concept Design Level**							**$8,922,095**	**15.25%**
	Totals For All Items	**6060**	**$42,002,549**	**$--**	**$424,211**	**$49,142,982**	**$--**	**$58,489,288**	**100%**

E.3.2 Method A: Service Cost Estimate

Table E-10 summarizes the service cost estimate. Service costs cover charges from the sewage treatment plant, electrical costs, labor costs, maintenance, and other continuing costs to operate the shore-based treatment, via the municipal sewage treatment plant. Rates for various utility services such as electricity and sewage come from a high-level survey of utility providers in the Great Lakes region (KPFF, 2011; Minnesota Power, 2011).

E.3.3 Method A: Drawings

Figure E-5 shows the system installation drawings.

Table E-10. Method A: service cost estimate.

Summary

This spreadsheet provides a rough estimate of the service costs for a shore based ballast water treatment facility, using municipal sewage services (Method A). The service costs involve fixed purchase costs and loan repayments, annual costs for maintenance and operation, and service costs from utility suppliers such as electricity and sewage treatment.

References

1. "Average Rate (cents/kWh)." Electric Rates, Minnesota Power. Last updated 2011. Last visited August 24, 2011. Available At: http://www.mnpower.com/econdev/about/electric_rates.html

Fixed Costs

These costs cover the initial purchase, which is converted to an annual cost of loan repayment.

Description	*Formula*	*Value*	*Units*
Initial purchase cost	P =	$ 58,489,288	*USD*
Assumed interest rate	i =	6.00%	*APR*
Payment period	n =	20	*years*
Annual payment	$A = \frac{i(1+i)^n}{(1+i)^n - 1} P$	**$ 5,099,363**	***USD/year***

Annual Costs

Annual costs recur every year. The total annual cost is first determined. Then total ballast water processed at a port is used to calculate the service cost necessary to cover these annual costs. Understand that this is only part of the total service cost.

1.) Loan Payments

Description	*Formula*	*Value*	*Units*
Annual payment	**A_p =**	**$ 5,099,363**	***USD/year***

2.) Labor Costs

Description	*Formula*	*Value*	*Units*
Employee hourly rate	r1 =	20.00	*$/hr*
Additional rate for employee benefits	r2 =	20.00	*$/hr*
Annual hours	h =	2,080.00	*hr*
Number of full time employees	n =	2.00	*people*
Annual labor cost	**A_l = n * h * (r1 + r2)**	**$ 166,400**	***USD/year***

Table E-10. Method A: service cost estimate. (Continued)

3.) Maintenance Costs

Description	*Formula*	*Value*	*Units*
Average volume of water processed (based on average of top 15% of all ports surveyed on the Great Lakes)	bw =	2,488,316	*m^3/year*
Maintenance cost per m^3 (Based on data from current BWT technologies and estimates of pump maintenance. Best reference available at concept level design.) Note: Currently under development	mr = (Under development)	$ 0.0002	*$/m^3*
Annual maintenance cost	**A_m = bw * mr**	**$ 434**	***USD/year***

4.) Infrastructure Costs

Description	*Formula*	*Value*	*Units*
Annual hours of operation	h1 =	2,080	*hr*
Electricity cost (Reference 1)	c1 =	$ 0.104	*$/kWh*
Added cost factor (to account for other infrastructure costs)	f =	2.00	-
Average power useage (infrastructure only)	P1 =	350.00	*kW*
Annual infrastructure cost	**A_i = h1 * c1 * f * P1**	**$ 150,842**	***USD/year***

Base Service Rate

Calculate base service rate to cover all annual costs.

Description	*Formula*	*Value*	*Units*
Annual payment	A_p =	$ 5,099,363	*USD/year*
Annual labor	A_l =	$ 166,400	*USD/year*
Annual maintenance	A_m =	$ 434	*USD/year*
Annual infrastructure	A_i =	$ 150,842	*USD/year*
Total annual cost	A = A_p + A_l + A_m + A_i	$ 5,417,038	*USD/year*
Average volume of water processed (based on average of top 15% of all ports surveyed on the Great Lakes)	bw =	2,488,316	*m^3/year*
Base service cost	**r_b = A / bw**	**$ 2.18**	***USD/m^3***

Table E-10. Method A: service cost estimate. (Continued)

Sewage System Service Rate

Calculate sewage system service rate.

Description	*Formula*	*Value*	*Units*
Minimum surveyed service rate	r_1 =	$ 0.41	*USD/m^3*
Maximum surveyed service rate	r_2 =	$ 1.31	*USD/m^3*
Assume the sewage system charges a premium to process such large quantities of ballast water. To reflect this, use 2/3 average between the minimum and maximum service rate.			
Sewage service rate	**r_s = (2/3) * (r_1 + r_2) /2**	**$ 1.29**	***USD/m^3***

Electric Service Rate

Calculate service rate for power to run major electrical pumps.

Description	*Formula*	*Value*	*Units*
Pumping power - booster pumps	P_p =	1,503.00	*kW*
Flow rate	Q =	11,810.48	*m^3/hr*
Electric service rate (Reference 1)	c1 =	$ 0.104	*$/kWh*
Electric service rate	**r_e = P_p * c1 / Q**	**$ 0.01**	***USD/m^3***

Total Service Rate

Total service rate charged to customer in order to process ballast water.

Description	*Formula*	*Value*	*Units*
Base service rate	r_b =	$ 2.18	*USD/m^3*
Sewage service rate	r_s =	$ 1.29	*USD/m^3*
Electric servcie rate	r_e =	$ 0.01	*USD/m^3*
Total service rate	**r = r_b + r_s + r_e**	**$ 3.48**	***USD/m^3***
		$ 13.17	*USD/ 1000 gal*

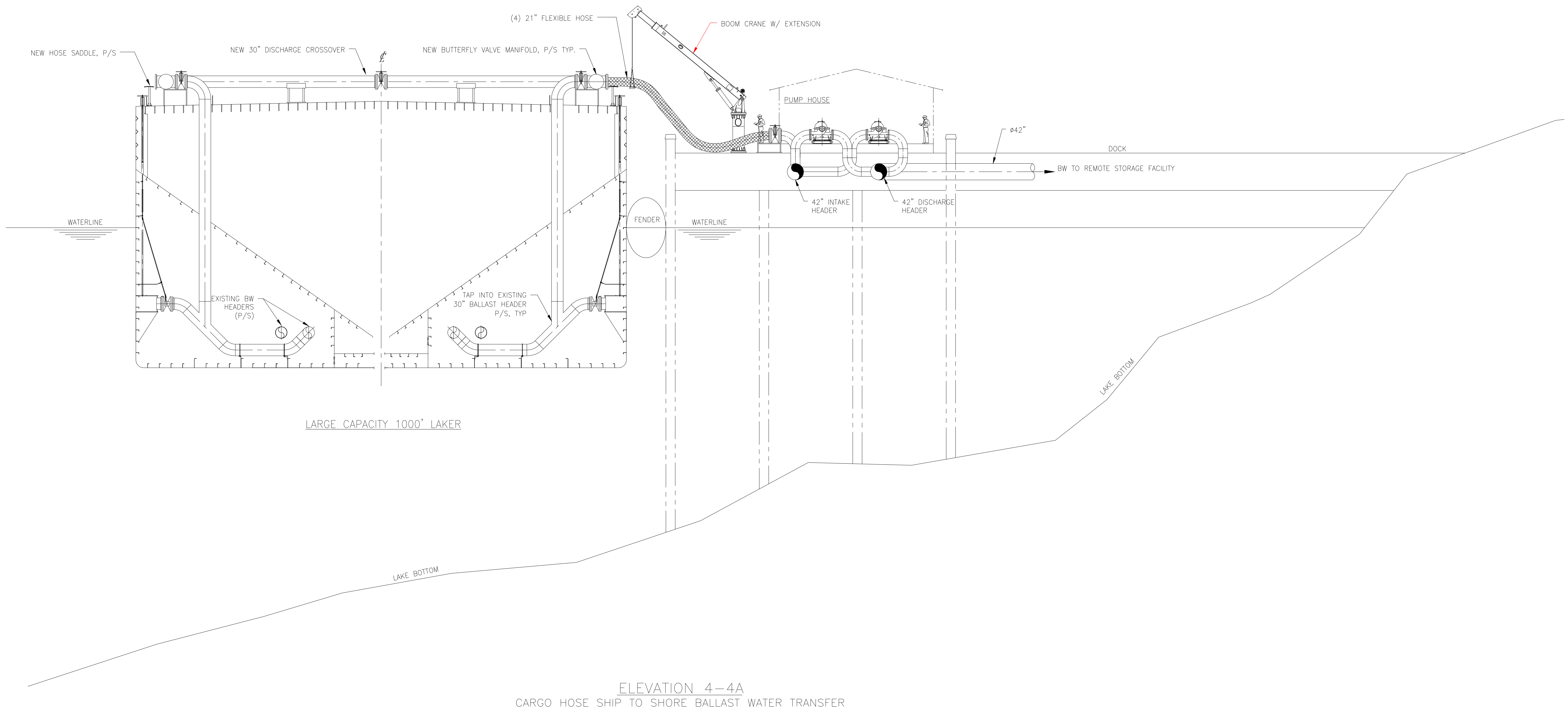


Figure E-5. Method A: ballast water transfer hose to shore-side system.

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APPENDIX F ALTERNATIVE BWM METHOD B – DEDICATED BWTF: SUPPORTING DOCUMENTS

F.1 Method B: Shore-side Facilities

F.1.1 Method B: Shore-side Facilities – Transition Piping

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- Total piping distance from the shore-side facility to the BWTF is 500' (152 m).
- Geographic elevation change from the shore-side facility to the BWTF is 10' (3.0 m).
- Anticipated flow rate is 52,000 gpm (11,810 m^3/hr).
- Total flow rate is achieved through four 16" inside diameter pipes. This allows more flexibility to avoid conflict with existing utility systems.
- All pressures are relative to an atmospheric pressure of 14.7 psi (101.3 kPa).
- Pressure at end of transition piping is a head of 24' (7.3 m).

Pipe material can be either ductile iron, PVC pipe, or fusion-welded HDPE. Internal pipe diameter is 16.0" minimum. Piping is buried a sufficient distance below grade for proper pipe protection and compliance with any pertinent regulations.

F.1.2 Method B: Shore-side Facilities – Booster Pumps

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- Total required pump head is 16.6 psi (114 kPa) (38.29' (38.29 m) of total head).
- Total required flow rate for system is 52,000 gpm (11,810 m^3/hr).
- System is required to have backup redundancy.

Total required flow rate is 52,000 gpm (11,810 m^3/hr), at a total pressure head of 16.6 psi (114 kPa). An array of four pumps in parallel are required, with one spare pump (5 pumps total). All pumps are identical. Individual pump requirements are 13,000 gpm (2,952.6 m^3/hr) at 16.6 psi (114 kPa); Goulds Pumps model 3420, size 20" x 24" or similar meets the pump requirements. Pump types are centrifugal, driven by 3-phase, 440 V, electric induction motors with variable frequency drives. Estimated required motor power is 150 hp (112 kW). Inlet nominal diameter is 20" and outlet diameter is 20". Pump motors have electronic control systems that all feed into a single user control panel.

The pump arrangement has a header on the inlet side and a second header on the outlet side. Both headers are square tubing, cross-section of 42.0" x 42.0". Individual header branches are 20.0" pipe with a bolted flange connection. Each branch connection requires a butterfly valve. This header arrangement applies to both the inlet and outlet pump headers. Each header should have drain plugs. Suitable foundations should be designed and provided to mount each header under the shore-side loading facility.

Figure F-1 shows the calculations for pressure drop of piping from the dock side to the BWTF. Piping includes the head from the 24' (7.3 m) tall storage tank. Total calculated pressure drop is 16.6 psi (114 kPa).

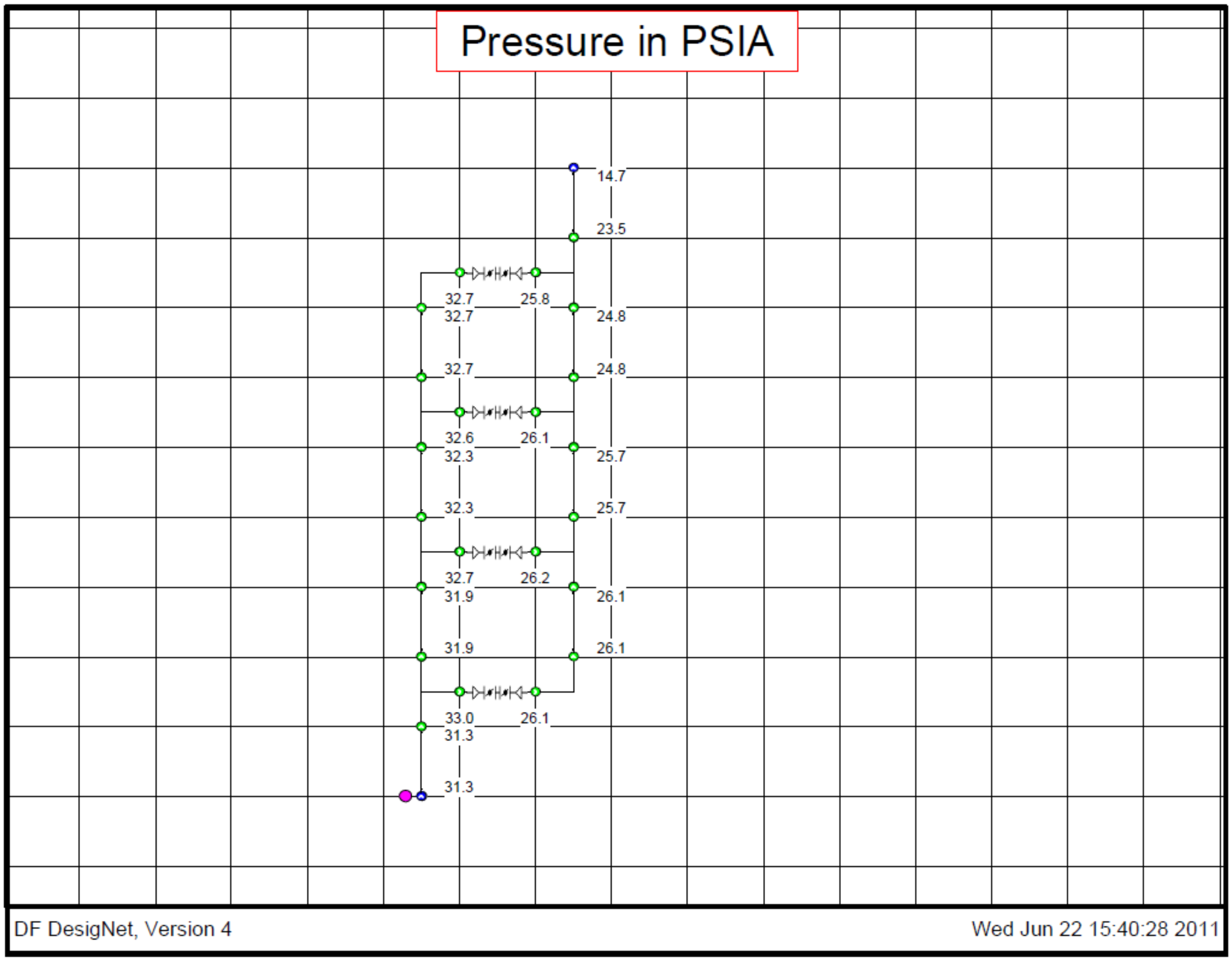


Figure F-1. Method B: pressure drop calculation.

Figure F-2 shows the pump curve for the booster pumps (Goulds Pumps 3420, August 25, 2011).

F.1.3 Method B: Shore-side Facilities – Buffer Tanks

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- The BWTF is located at a site near the loading facility.
- The BWTF treatment flow rate must match or exceed the ballast discharge rate of the largest vessel.

The BWT buffer system requires two buffer tanks. Each tank has a storage capacity of 361,544 gal (1,368.6 m^3). Total storage capacity must be 723,088 gal (2,737.2 m^3).

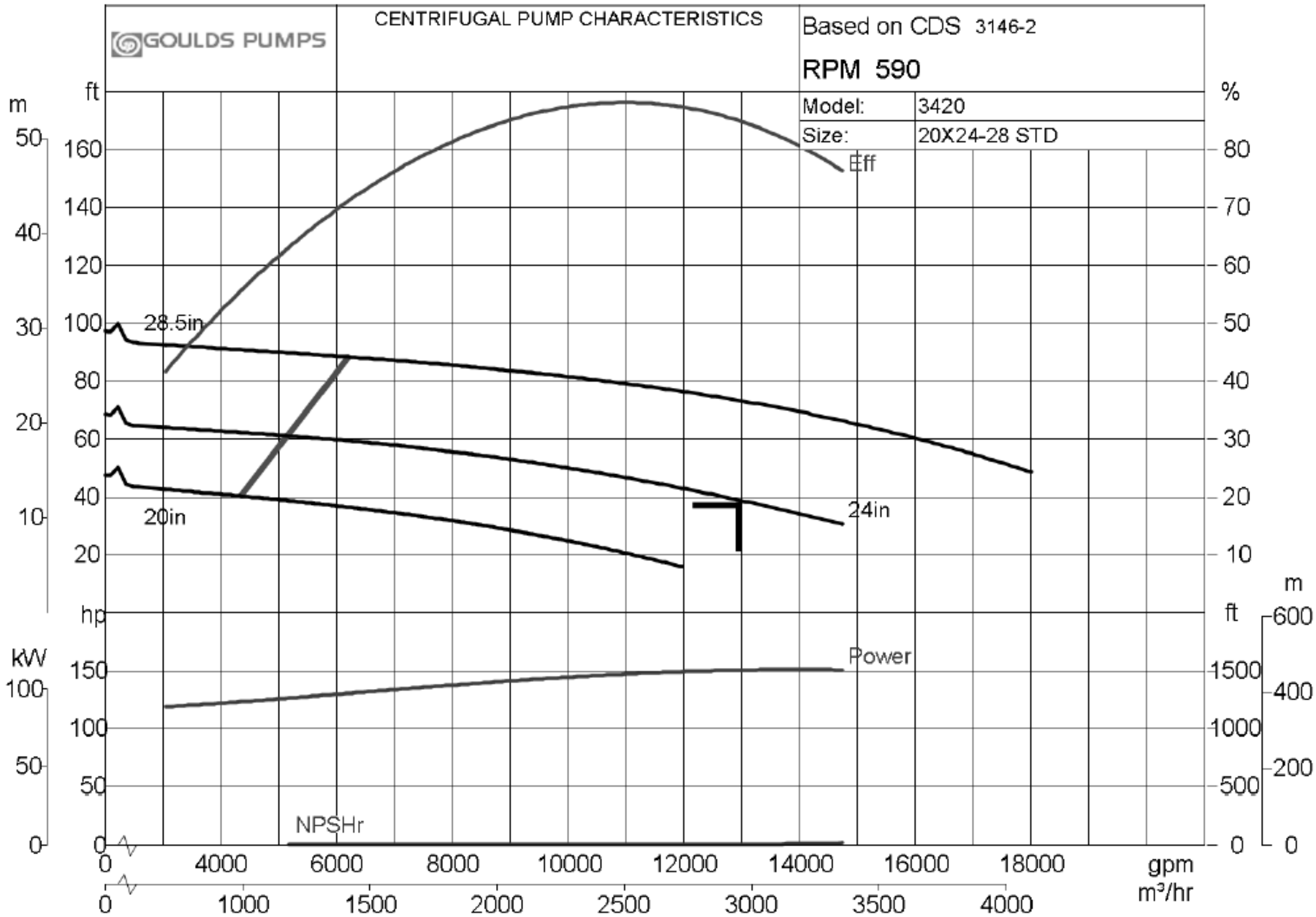


Figure F-2. Method B: pump system curve for booster pumps: Method B.

Tanks must be cylindrical shaped. Tanks are Superior Tanks model 50' 6-1/16" x 24' 1-1/2" or similar (Superior Tank Company, Inc., June 9, 2011). Tanks are mild steel bolted plates. Bolted connections must be appropriately watertight. All steel surfaces, internal and external, must be coated for protection against corrosion. Suitable foundation should be provided for storage tanks. Storage tanks should be secured and anchored to withstand all anticipated weather for the site, without damage to the tank. Weather should be assumed to include a 600-year storm.

Each tank must be vented. There should be access stairways to reach the top of tank and access holes at the top of the tank for tank maintenance. A permanent ladder should be installed inside the tank for personnel access. Automated lighting should be installed on the top of the tank to notify low flying aircraft. A 20.0" inner diameter pipe should be installed at the center of the tank floor. Near the tank, a 20.0" gate valve with electronic motor should be installed. All connections are bolted flange or welded.

The tank pipe connection must feed into a pipe distribution system. Four main transition pipes carry the ballast water into the storage facility. Ballast water from those pipes must be capable of routing to any individual tank or any combination of one or two storage tanks simultaneously. Pipe material can be either ductile iron, PVC pipe, or fusion-welded HDPE.

The distribution system must also be capable of draining any individual tank or any combination of one or two storage tanks simultaneously. Pipe material can be either ductile iron, PVC pipe, or fusion-welded HDPE. The drainage must feed into the BWTF. This drainage must occur at the same time that incoming ballast water flows into other buffer tanks. Mixing of the inflow and outflow ballast water is permitted. The inflow ballast water must not pressurize the outflow ballast water in excess of a head of 24.0' (7.32 m).

The pressure loss from all distribution piping and fittings must not exceed a pressure drop of 6.0 psi (41 kPa). All valves are butterfly type with electronic motor controls. All motors must run by a central computer control system. The system must be capable of local or remote operation. There should be an electronic link to a monitoring station back at the loading facility. All wiring and an electric distribution network should be provided to power automated tank lighting, distribution system motors, and distribution system controls.

The following calculations estimate required storage capacity, based on the assumptions already detailed (Table F-1).

Table F-1. Method B: storage tank capacity calculations.

Summary

This spreadsheet estimated the required capacity of the ballast storage facility.

Total Ballast Capacity

Largest vessel		1000 foot class	
Largest vessel ballast capacity	V1 =	16,425,462	*gal*
Ballast discharge time	T1 =	6.62	*hr*
Ballast discharge rate	Rd =	2,481,188	*gal/hr*
Assume 9 hour period between vessels docking			
Period between docking	T2 =	7.00	*hr*
Ballast processing rate	Rs =	3,120,000	*gal/hr*
Net flow rate	Rn = Rd - Rs	0	*gal/hr*
Excess ballast water	V2 = T1 * Rn	0	*gal*
Time to process excess ballast water	T3 = V2 / Rs	0.00	*hr*
Assume a worst case scenario of one 1000 foot class vessel docking and a second 1000 foot class vessel the very next day.			
Ballast still stored when next vessel arrives	V3 = V2 - Rs * (T2 - T1)	0	*gal*
Safety factor	SF =	1.20	-
Total ballast storage capacity needed	**V4 = SF * (V3 + V2)**	**0**	***gal***

Individual Tank Size

The ballast water will be stored in multiple tanks. A suitable minimum tank size must be determined.

Required storage capacity	V4 =	0	*gal*
Number of tanks (rounded up)	N =	2	-
Individual storage tank diameter	d =	50.5	*ft*
Individual storage tank height	h =	24.1	*ft*
Individual storage tank volume	Vind =	361,544	*gal*
Total available storage volume	V = N * Vind	723,088	*gal*

F.1.4 Method B: Shore-side Facilities – BWT Equipment

F.1.4.1 Method B: Shore-side Facilities, BWT Equipment – Assumptions

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- Hyde Guardian model HG6000 by Calgon Carbon is selected for BWT units. This is due to convenience of available information and does not constitute an endorsement for Hyde Guardian.
- Dedicated BWTF must handle a large range of ballast flow rates for all types of vessels.
- BWT plant must provide treatment for vessels discharging and taking on ballast water.

F.1.4.2 Method B: Shore-side Facilities, BWT Equipment – Description

BWT equipment must accommodate ballast flow rates from 4,403 gpm (1000 m^3/hr) to 52,000 gpm (11,810 m^3/hr). Plant must adjust treatment flow rates with a maximum resolution of 6,600 gpm (1,500 m^3/hr). Finer resolution for flow rate adjustment is acceptable. Two units of Hyde Guardian HG6000 by Calgon Carbon, or similar, should be supplied. Installation arrangement should have each HG6000 unit operate independently. Piping arrangement and valves should be provided to isolate each UV reactor within the HG6000 unit and each Superflow filter within each unit. At a minimum, three Superflow filters must be energized at all times. All system control valves are butterfly type with electronic motor control.

Suitable foundations should be designed and provided for all BWT equipment. Raised platforms and catwalks should be designed and provided for easy personnel access to BWT equipment. An overhead track crane should be provided for equipment handling. Crane load capacity must be 2650 lb (1202 kilograms (kg)) or greater. Crane range of motion must ensure access to all major plant equipment. Logical arrangements for locations of all electrical power panels and control system should be provided. All local control systems must use Ethernet connections for data transfer. Two remote user control panels should be provided. The first remote panel is located within a central control office at the BWT plant. The second control panel is located at remote control office located back at the vessel loading facility. Arrangement and functionality of remote control panels must be identical.

All BWT units must feed into a common discharge pipe, or set of pipes. All treated ballast water must discharge into the nearest natural water body. It should be ensured that ballast water discharge will not significantly alter the ecosystem of the water body. Examples include raising water levels or altering salinity. A suction pipe, or set of pipes, should be provided to take ballast water in to treatment plant. All piping should be sized for acceptable friction head loss.

Plant must treat water discharged from vessels, and it must provide treated ballast water to vessels when taking on ballast. This is necessary because IMO approval currently requires treatment on vessel ballast intake and discharge. Alternatively, obtain successful IMO approval to only treat ballast water on discharge.

All system back-flush water is considered contaminated and must be treated before discharge into water bodies. All back-flush water must be routed to a single storage tank. Provide storage tank for system back-flush water. Metered flow pump should be provided to discharge back-flush water into municipal sewage system at a rate the sewage system can accommodate.

F.1.5 Method B: Shore-side Facilities – Back-flush Water Storage Tank

F.1.5.1 Method B: Shore-side Facilities, Back-flush Water Storage Tank – Assumptions

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- System back-flush water cannot be processed by regular BWT equipment due to the high particulate content.
- System back-flush water remains contaminated with invasive organisms and must be treated.

F.1.5.2 Method B: Shore-side Facilities, Back-flush Water Storage Tank – Description

The back-flush water storage system requires one storage tank. The tank must have a storage capacity of 165,460 gal (626.3 m^3).

Tanks must be cylindrical shaped. Tanks are Superior Tanks model 34' 2" x 24' 1-1/2" or similar (Superior Tank Company, Inc., June 9, 2011). Tanks are mild steel, uniform welded surface. All welded connections must be appropriately watertight. All steel surfaces, internal and external, must be coated for protection against corrosion. A suitable foundation should be provided for storage tanks. Storage tanks should be secured and anchored to withstand all anticipated weather for the site, without damage to the tank. Weather should be assumed to include a 600-year storm.

Each tank must be vented. There should be access stairways to reach the top of tank and access holes at the top of the tank for tank maintenance. A permanent ladder should be installed inside the tank for personnel access. An automated agitator should be installed to prevent particulates from adhering to tank walls. A 6.0" nominal diameter pipe should be installed at the center of the tank floor. A 6.0" gate valve with electronic motor should be installed in the pipe at the tank. All connections are bolted flange or welded.

The tank pipe connection must feed into a municipal sewage system outlet. Pipe material can be either ductile iron, PVC pipe, or fusion-welded HDPE. The sewage outlet must also be capable of draining either individual tank. This drainage must occur at the same time that incoming back-flush water flows into storage tank. Inflow and outflow back-flush water are permitted to mix. The inflow back-flush water must not pressurize the outflow back-flush water in excess of a head of 24.0'.

Ensure reasonable pressure loss from all piping and fittings. All system control valves are butterfly type with electronic motor controls. All motors must run by a central computer control system. The system must be capable of local or remote operation. Table F-2 estimates required back-flush water storage capacity, based on the assumptions already detailed.

F.1.6 Method B: Shore-side Facilities – Outlet to Municipal Sewer

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- Sewage system can accept ballast water at a rate of 650 gpm (148 m^3/hr).
- Sewage treatment plant has the capacity to accept this ballast water in addition to normal sewage and storm drain water.

Table F-2. Method B: calculations for back-flush storage tank.

Summary

This spreadsheet estimated the required capacity of the ballast flush water storage tank.

Total Flush Water Capacity

Largest vessel		1000 foot class	
Largest vessel ballast capacity	V1 =	16,425,462	*gal*
System flush water percent of ballast flow rate	pF =	1.50%	
Flush water capacity	V1f = V1 * pF	246,382	*gal*
Ballast discharge time	T1 =	6.62	*hr*
Assume 9 hour period between vessels docking			
Period between docking	T2 =	9.00	*hr*
Assumed sewage system metering rate	Rs =	39,000	*gal/hr*
Time to empty ballast into sewage system	T3 = V1f / Rs	6.32	*hr*
Assume a worst case scenario of one 1000 foot class vessel docking and a second 1000 foot class vessel docking directly after the first. No other vessels dock afterwards.			
Ballast still stored after first	V2 = V1f - Rs * T2	-104,618	*gal*
Safety factor	SF =	1.20	-
Total ballast storage capacity	**V3 = SF * (V2 + V1f)**	**170,117**	***gal***

Individual Tank Size

The ballast water will be stored in multiple tanks. A suitable minimum tank size must be determined.

Required storage capacity	V4 =	170,117	*gal*
Number of tanks (rounded up)	N =	1	-
Individual storage tank diameter	d =	34.2	*ft*
Individual storage tank height	h =	24.1	*ft*
Individual storage tank volume	Vind =	165,460	*gal*
Total available storage volume	V = N * Vind	165,460	*gal*

- Sewage treatment plant possesses the necessary machinery and techniques to sterilize ballast water in accordance with the requirements of IMO approval guidelines (Marine Environmental Protection Committee, IMO, October 2008).
- Sewage system infrastructure has a pipeline within 50' of the ballast storage facility that can accept the ballast water at a flow rate of 650 gpm (148 m^3/hr).
- The same level of redundancy installed in the rest of the ballast treatment system is maintained in the sewage outlet pumps.
- Outlet to sewage system requires a vertical elevation change of 20.0' (6.1 m)

Pipe material can be either ductile iron, PVC pipe, or fusion-welded HDPE. At this outlet, the pipes split into two parallel pumps. Just before the inlet to each pump, install a manual operated butterfly valve and a digital flow meter. Flow meter should provide sensor data to the control system for the ballast storage facility. At the outlet to the pump, install a manual operated butterfly valve. Provide bolted flange connections. System should be designed with the capability to remove one pump for maintenance without stopping system operation.

Pumps must have a flow capacity of 650 gpm (148 m^3/hr) at a differential pressure of 8.80 psi (60.7 kPa). Goulds Pumps model 5500 or similar is recommended (Goulds Pumps 5500, August 24, 2011). Pumps should be identical models. Minimum required efficiency for each pump is 70 percent. Each pump is driven by a 5.0 hp electric motor. Motor is 3-phase, 240 V, induction type with a variable frequency drive. Variable frequency drive is controlled by the control system for the ballast treatment facility. Drive is adjusted to maintain a constant flow rate of 650 gpm (148 m^3/hr). Only one pump is needed to maintain this flow rate. The second pump acts as a backup.

Figure F-3 shows the pressure drop for the sewage outlet pumps under the assumed conditions previously stated. The diagram reflects that only one pump is active.

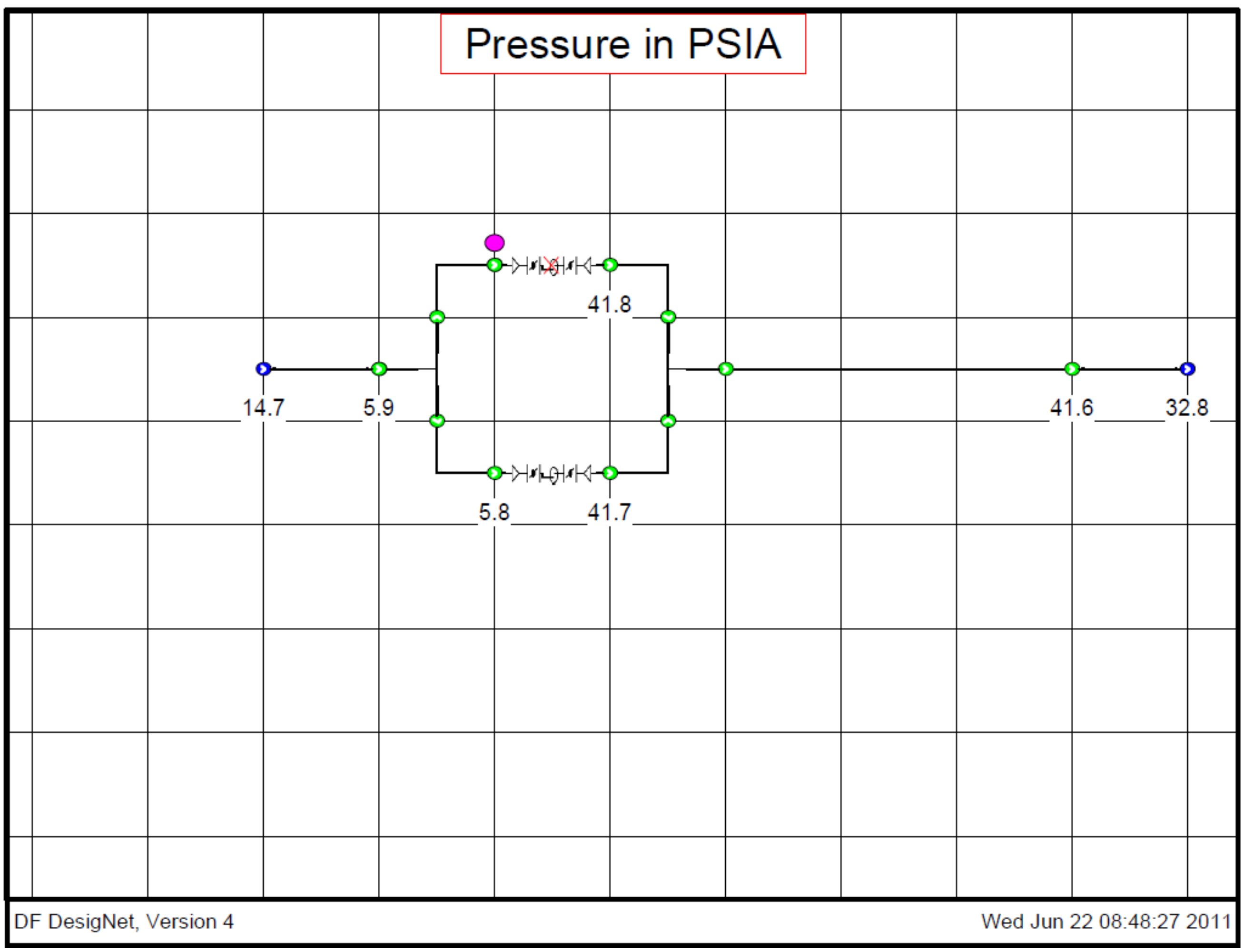


Figure F-3. Method B: pressure drop calculation for sewage outlet pumps.

Using the information from the system pressure drop, a pump can be selected. Figure F-4 gives the pump performance curve for one sewage system outlet pump.

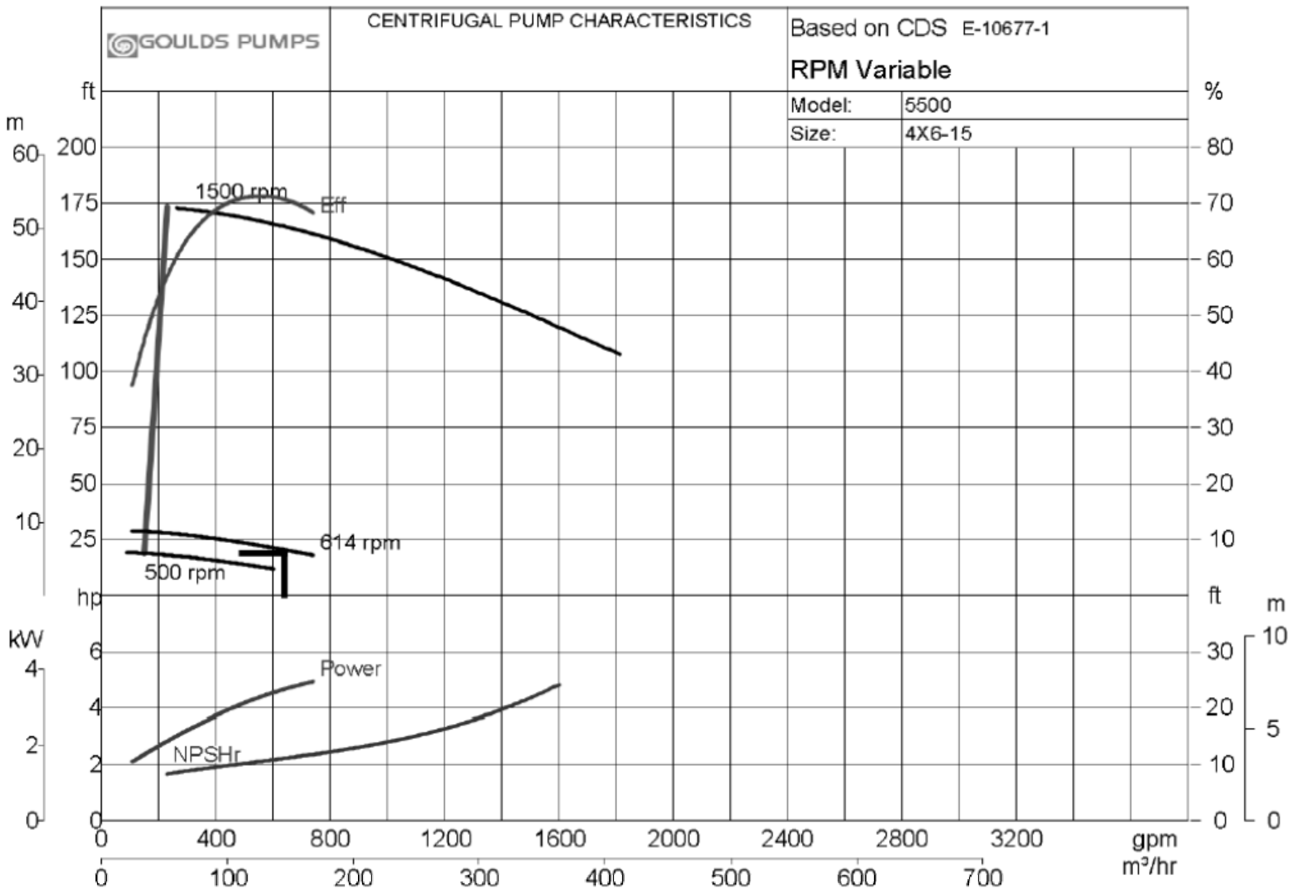


Figure F-4. Method B: pump curve: sewage system outlet pump.

F.1.7 Method B: Shore-side Facilities – Support Infrastructure

F.1.7.1 Method B: Shore-side Facilities, Support Infrastructure – Assumptions

Design specifications make the following assumptions. Specifications and design should be reexamined if any of these assumptions are not valid and reasonable.

- BWTF operates autonomously with only occasional visits from workers for system maintenance.
- Facilities at loading dock are staffed by two full-time personnel to handle connections with vessels and monitor ballast water transfer.

F.1.7.2 Method B: Shore-side Facilities, Support Infrastructure – Description

The BWTF requires all necessary support infrastructures for a processing plant. This includes a permanent enclosed building, office equipment, maintenance equipment, and environmental systems. If the BWTF is installed in an existing facility, most of these infrastructure requirements are not applicable.

1. Provide paved roadway access to the BWTF from the nearest public road. Obtain all necessary permits. Provide parking at the BWTF for up to two cars, plus one Americans with Disabilities Act (ADA) parking space.

2. Provide main electric supply from the local electric utility. Calculate anticipated power factor of the system predominant operating conditions. If calculated power factor is below 80 percent, provide suitable compensation (inductors or capacitors as necessary) to raise power factor up to 96 percent.
3. Provide automated control system for all motor pumps and BWT equipment within the BWTF. Control system must have local user interface and remote user interface at the vessel loading facility. Control system must provide warnings (audible and visible) for system failure or power failure, including failure of the user interface. Design control system with fail-safe actions in the event of system failure. Install main control system components at BWTF. Install remote user interface at vessel loading dock. Provide linkage between two sites.
4. Install telephone communications system at BWTF.
5. Provide a permanent building to house control system, office space, control room, maintenance space, and BWT equipment. Building must be weather-tight, able to withstand all reasonable weather for the region, and secure against vandalism. Building foundation must include suitable mounting for the BWT equipment. Building must have suitable ventilation for the BWT equipment to operate.

F.2 Method B: Cost Estimates

F.2.1 Method B: Installation Cost Estimate

Table F-3 summarizes installation cost estimates of $18,806,685 for the dedicated, shore-side treatment facility. Cost estimates include modifications to vessels, installation of shore connection equipment, installation of the BWTF, and any support infrastructure (Regents of the University of Minnesota, 2011).

F.2.2 Method B: Service Cost Estimate

Table F-4 summarizes the service cost estimate. Service costs cover charges from the sewage treatment plant, electrical costs, labor costs, maintenance, and other continuing costs to operate the shore-based treatment facility. Rates for various utility services such as electricity and sewage come from a high-level survey of utility providers in the Great Lakes region (KPFF, 2011; Minnesota Power, 2011).

F.3 Method B: Construction Gantt Chart

A project plan outline with a Gantt Chart is shown in Figure F-5. The plan identifies critical steps and estimated time lines for detailed engineering and design, permitting, bid process, materials and equipment purchases, and phases of construction and testing.

F.4 Method B: Drawings

Figure F-6 shows the drawing.

Table F-3. Method B: installation cost estimate summary.

Cost Estimate Summary: Shore-side Facilities, Method B - Dedicated BWTF											
SWBS No.	**Item Description**	**Labor Hours**	**Material & Services @ Cost ($)**	**Subcontracts @ Cost ($)**	**Labor Cost @ $70/Hr**	**Material & Services w/17% Mark-up ($)**	**Subcontracts w/17% Mark-up ($)**	**Item Total Costs**	**Percent of Total Cost**		**Item Total Costs: No Infrastructure**
000	Project Management, Permits, etc.	12427	$169,344	$--	$869,873	$198,132	$--	$1,068,005	5.68%		$1,068,005
100	Pier Structure, Foundations, Berms	0	$--	$--	$--	$--	$--	$-	0.00%		$--
200	Shore Connection Equipment	0	$2,306,312	$--	$--	$2,698,385	$--	$2,698,385	14.35%		$2,698,385
300	Power & Lighting System	0	$224,000	$--	$--	$262,080	$--	$262,080	1.39%		$262,080
400	Controls, Monitoring, Alarms, etc.	179.2	$50,831	$--	$12,544	$59,473	$--	$72,017	0.38%		$72,017
500	Manifolds & Piping Systems	0	$2,400,720	$--	$--	$2,808,842	$--	$2,808,842	14.94%		$2,808,842
600	Buildings, Shelters, Fences	13238.4	$1,129,856	$--	$926,688	$1,321,932	$--	$2,248,620	11.96%		$--
700	BWT System	358.4	$4,760,000	$--	$25,088	$5,569,200	$--	$5,594,288	29.75%		$5,594,288
800	Integration & Engineering	89.6	$1,008,000	$--	$6,272	$1,179,360	$--	$1,185,632	6.30%		$1,185,632
900	Equip't Rentals, Heavy Lift Cranes	0	$--	$--	$--	$--	$--	$--	0.00%		$--
	Contingency @ 18% **Based on Concept Design Level**							**$2,868,816**	**15.25%**		**$2,868,816**
	Totals for All Items	**26292**	**$12,049,063**	**$-**	**$1,840,465**	**$14,097,404**	**$-**	**$18,806,685**	**100%**		**$16,558,066**

Table F-4. Method B: service cost estimate summary.

Summary

This spreadsheet provides a rough estimate of the service costs for a shore based ballast water treatment facility, using a dedicated ballast water treatment facilities (Method B). The service costs involve fixed purchase costs and loan repayments, annual costs for maintenance and operation, and service costs from utility suppliers such as electricity and sewage treatment.

References

1. "Average Rate (cents/kWh)." Electric Rates, Minnesota Power. Last updated 2011. Last visited August 24, 2011. Available At: http://www.mnpower.com/econdev/about/electric_rates.html

Fixed Costs

These costs cover the initial purchase, which is converted to an annual cost of loan repayment. Costs assume a blank slate loading terminal that requires new facilities for the BWTF.

Description	*Formula*	*Value*	*Units*
Initial purchase cost	P =	$ 18,806,685	*USD*
Assumed interest rate	i =	6.00%	*APR*
Payment period	n =	20	*years*
Annual payment	$A = \frac{i(1+i)^n}{(1+i)^n - 1} P$	**$ 1,639,653**	***USD/year***

Annual Costs

Annual costs recur every year. The total annual cost is first determined. Then total ballast water processed at a port is used to calculate the service cost necessary to cover these annual costs. Understand that this is only part of the total service cost.

1.) Loan Payments

Description	*Formula*	*Value*	*Units*
Annual payment	**A_p =**	**$ 1,639,653**	***USD/year***

2.) Labor Costs

Description	*Formula*	*Value*	*Units*
Employee hourly rate	r1 =	20.00	*$/hr*
Additional rate for employee benefits	r2 =	20.00	*$/hr*
Annual hours	h =	2,080.00	*hr*
Number of full time employees	n =	2.00	*people*
Annual labor cost	**A_l = n * h * (r1 + r2)**	**$ 166,400**	***USD/year***

Table F-4. Method B: service cost estimate summary. (Continued)

3.) Maintenance Costs

Description	*Formula*	*Value*	*Units*
Average volume of water processed (based on average of top 15% of all ports surveyed on the Great Lakes)	bw =	2,488,316	*m^3/year*
Maintenance cost per m^3 (Based on data from current BWT technologies and estimates of pump maintenance. Best reference available at concept level design.)	mr =	$ 0.0018	*$/m^3*
Annual maintenance cost	**A_m = bw * mr**	**$ 4,456**	***USD/year***

4.) Infrastructure Costs

Description	*Formula*	*Value*	*Units*
Annual hours of operation	h1 =	2,080	*hr*
Electricity cost (Reference 1)	c1 =	$ 0.104	*$/kWh*
Added cost factor (to account for other infrastructure costs)	f=	2.00	-
Average power useage (infrastructure only)	P1 =	350.00	*kW*
Annual infrastructure cost	**A_i = h1 * c1 * f * P1**	**$ 150,842**	***USD/year***

Base Service Rate

Calculate base service rate to cover all annual costs.

Description	*Formula*	*Value*	*Units*
Annual payment	A_p =	$ 1,639,653	*USD/year*
Annual labor	A_l=	$ 166,400	*USD/year*
Annual maintenance	A_m=	$ 4,456	*USD/year*
Annual infrastructure	A_i=	$ 150,842	*USD/year*
Total annual cost	A = A_p + A_l+ A_m + A_i	$ 1,961,350	*USD/year*
Average volume of water processed (based on average of top 15% of all ports surveyed on the Great Lakes)	bw =	2,488,316	*m^3/year*
Base service cost	**r_b = A / bw**	**$ 0.79**	***USD/m^3***

Table F-4. Method B: service cost estimate summary. (Continued)

Sewage System Service Rate - Backwash Water

Calculate sewage system service rate. The full amount of ballast water is not processed by the sewage system. However, the BWTF does have some untreated process byproduct that still requires sanitization.

Description	*Formula*	*Value*	*Units*
Minimum surveyed service rate	r_1 =	$ 0.41	*USD/m^3*
Maximum surveyed service rate	r_2 =	$ 1.31	*USD/m^3*
Assume the sewage system charges a premium to process backwash water. To reflect this, use 2/3 average between the minimum and maximum service rate.			
Ratio of water rejected to sewer compared to total ballast water received.	r_bw =	1.50%	
Sewage service rate	**r_s = r_bw * (2/3) * (r_1 + r_2) /2**	**$ 0.02**	***USD/m^3***

Electric Service Rate

Calculate service rate for power to run major electrical pumps.

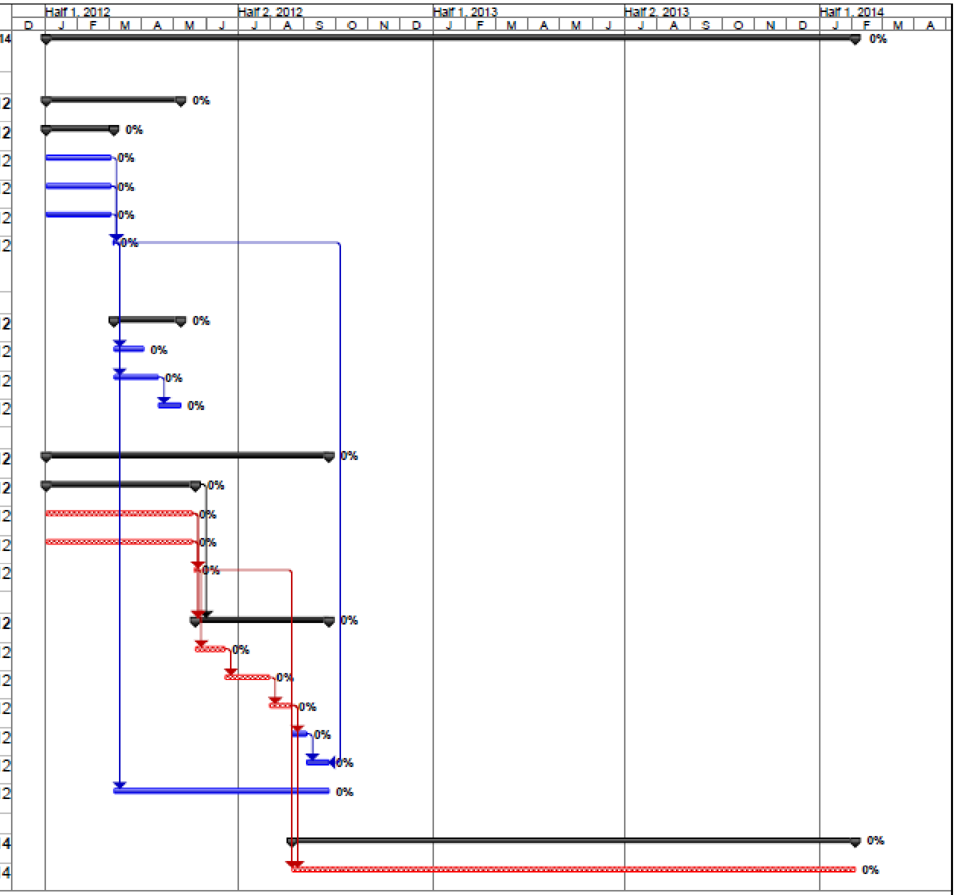
Description	*Formula*	*Value*	*Units*
Pumping power - booster pumps	P_p =	448.00	*kW*
BWT units power	P_bw =	1,710.00	*kW*
Flow rate	Q =	11,810.48	*m^3/hr*
Electric service rate (Reference 1)	c1 =	$ 0.104	*$/kWh*
Electric service rate	**r_e = (P_p + P_bw) * c1 / Q**	**$ 0.02**	***USD/m^3***

Total Service Rate

Total service rate charged to customer in order to process ballast water.

Description	*Formula*	*Value*	*Units*
Base service rate	r_b =	$ 0.79	*USD/m^3*
Sewage service rate	r_s =	$ 0.02	*USD/m^3*
Electric servcie rate	r_e =	$ 0.02	*USD/m^3*
Total service rate	**r = r_b + r_s + r_e**	**$ 0.83**	***USD/m^3***
		$ 3.13	*USD/ 1000 gal*

ID	Task Name	Duration	Start	Finish
1	**Ballast Water Treatment Facility**	546 days	Mon 1/2/12	Mon 2/3/14
2				
3	**Preliminary Design**	91 days	Mon 1/2/12	Mon 5/7/12
4	**Preliminary Design Development**	46 days	Mon 1/2/12	Mon 3/5/12
5	Sewer Adequacy Study	45 days	Mon 1/2/12	Fri 3/2/12
6	Preliminary Grading Study	45 days	Mon 1/2/12	Fri 3/2/12
7	Preliminary Utility Layout	45 days	Mon 1/2/12	Fri 3/2/12
8	Submit 50% Preliminary Design (USCG & Agency)	1 day	Mon 3/5/12	Mon 3/5/12
9				
10	**50% Review**	45 days	Tue 3/6/12	Mon 5/7/12
11	USCG Review Period	20 days	Tue 3/6/12	Mon 4/2/12
12	Agency Review Period	30 days	Tue 3/6/12	Mon 4/16/12
13	Respond to 50% Review Comments	15 days	Tue 4/17/12	Mon 5/7/12
14				
15	**Final Design & Permitting**	191 days	Mon 1/2/12	Mon 9/24/12
16	**Final Site Design and Development**	101 days	Mon 1/2/12	Mon 5/21/12
17	Final Grading Plan	100 days	Mon 1/2/12	Fri 5/18/12
18	Final Utility Layout	100 days	Mon 1/2/12	Fri 5/18/12
19	Submit 100% Final Design	1 day	Mon 5/21/12	Mon 5/21/12
20				
21	**100% Final Submission & Review**	90 days	Tue 5/22/12	Mon 9/24/12
22	USCG Review Period	20 days	Tue 5/22/12	Mon 6/18/12
23	Agency Review Period	30 days	Tue 6/19/12	Mon 7/30/12
24	Respond to 100% Review Comments	15 days	Tue 7/31/12	Mon 8/20/12
25	Final Site Plan revision (if needed)	10 days	Tue 8/21/12	Mon 9/3/12
26	Municipality Approval	15 days	Tue 9/4/12	Mon 9/24/12
27	Construction Permitting	145 days	Tue 3/6/12	Mon 9/24/12
28				
29	**Construction**	380 days	Tue 8/21/12	Mon 2/3/14
30	Procurement, Site Work, and Release	380 days	Tue 8/21/12	Mon 2/3/14



Critical		Task Progress		Summary Progress		Inactive Task		Manual Summary Rollup	
Critical Split		Baseline		Summary		Inactive Milestone		Manual Summary	
Critical Progress		Baseline Split		Project Summary		Inactive Summary		Start-only	
Task		Baseline Milestone		External Tasks		Manual Task		Finish-only	
Split		Milestone		External Milestone		Duration-only		Deadline	

Project: Ballast Water Treatment Facil
Date: Thu 8/4/11

Page 1

Figure F-5. Construction project Gantt chart.

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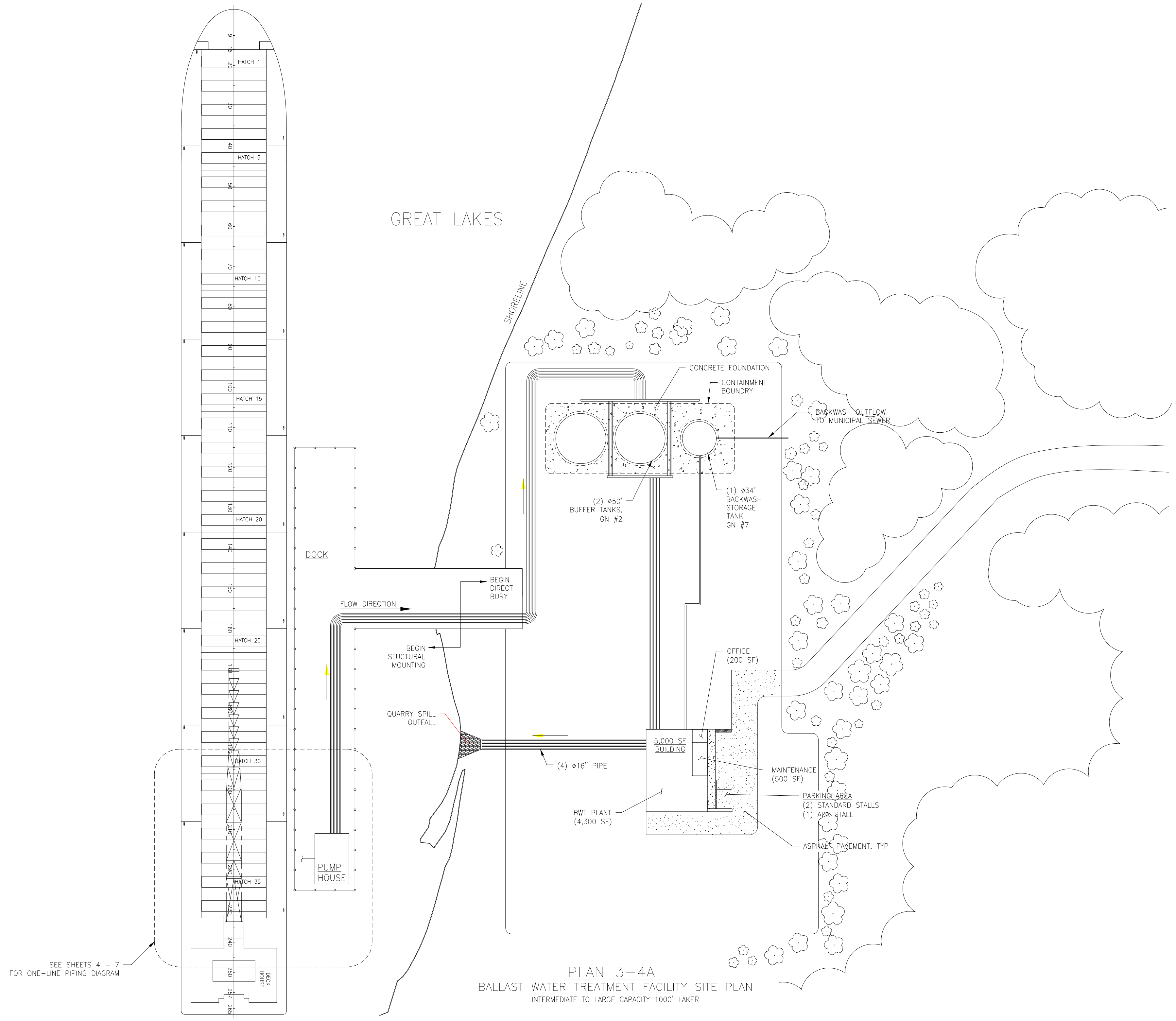

Figure F-6. Method B: vessel moored to pier.

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APPENDIX G ALTERNATE BWM METHODS, VESSEL PIPING MODIFICATIONS

G.1 Vessel One, Alternate BWM Methods: Alternate Piping Modifications

G.1.1 Vessel One, Alternate BWM Methods: Ballast System

The ballast system consisted of 18 independent ballast pumps. A single ballast pump, with its own independent piping system, services each ballast tank. The following system is common to each ballast tank. A ballast pump, exact model unknown, services each tank. Each centrifugal ballast pump has a 40' total head at a capacity of 3600 gpm. Each ballast system has a sea chest, which is used for both suction and discharge. The ballast pump is fitted with an electronic throttling valve on the pump discharge side.

G.1.2 Vessel One, Alternate BWM Methods: Shore Connection Pipe

The shore connection pipe requires a new common rail pipe, which links into each independent ballast pump; see Figure G-1. The following detail describes installation for the port side ballast pumps. Starboard side pumps are similar and opposite. Following is the installation description.

1. Install a new 28" diameter pipe that runs longitudinally along the length of the ship. This is designated the common rail pipe and will be installed in the port side pipe tunnel beneath the cargo holds.
2. All common rail pipe must stay inboard of the side shell by a distance of one-fifth the total ship beam.
3. Provide suitable supports for pipe. The new pipe will run the length of the pipe tunnel.
4. Branch connections to the pipe will be saddle type with full penetration welds.

The following typical configuration is used to install the branch connection. This connects the individual ballast pumps to the common rail system.

1. Install a new 10" pipe just after the electronic throttle valve.
2. In the new connection pipe, install an electronic-actuated 10" butterfly valve directly after the connection into the existing ballast system.
3. Provide wiring and controls to include the new electronic valve in the main ballast control system.
4. The new 10" connection pipe will connect into the common rail pipe. Use a T-type saddle connection with full penetration welds.
5. Position the connection pipe so that it is centered on the common rail pipe.
6. Just before the connection to the common rail pipe, install a check valve and stop valve with electronic actuation.
7. All valves should be capable of independent control and actuation.

A 30" pipe should be installed to connect the common rail to the deck manifold.

1. Route the 30" pipe outboard to beneath the deck then through to the deck and to the manifold. The piping can be outboard the one-fifth ship beam limit.

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SYMBOLS LIST

	NEW PIPE
	EXISTING PIPE
	BUTTERFLY VALVE REMOTE CONTROLLED
	BUTTERFLY VALVE
	BALL VALVE
	PIPE DOWN
	SWING CHECK VALVE
	FLANGE CONNECTION (QUICK CONNECT)
	CENTRIFUGAL PUMP
	BUTTERFLY VALVE MANIFOLD
	REDUCER
LA	MARINE LOADING ARM
	BHD/DECK PENETRATION
	SUCTION BELLMOUTH
	VENT
	BUTTERFLY VALVE REMOTELY OPERATED (AIR) W/ CAPABILITY OF MANUAL OPERATION
	DRESSER COUPLING W/ ANCHOR BOLTS
P	PRESSURE GAUGE
	BUTTERFLY VALVE REMOTELY OPERATED (ELEC) W/ CAPABILITY OF MANUAL OPERATION
	PLUG
	1/2" COUPLING & PLUG
	FLEXIBLE CONNECTION

MATERIAL SCHEDULE

SERVICE	SIZE	PIPE	TAKEDOWN JOINTS			FITTINGS	VALVES		REMARKS
			MATERIAL	GASKETS	BOLTING		BODY	TRIM	
BALLAST WATER (ON SHORE)	ALL	PVC SCH 80 ASTM D1785	SOCKET FLANGE PVC 150# ASTM D2467 ANSI B16.5	FULL FACE NEOPRENE 1/8" THICK	316 STAINLESS	PVC SCH 80 SOCKET UNION ASTM D2467 THREADED ASTM D2464 ASTM 1498	BUTTERFLY: PVC, ANSI B16.10 BALL: PVC, TRUE UNION ENDS	PVC DISC, SS STEM, FPM SEALS PVC BALL, SS STEM, FPM SEALS	–
BALLAST WATER (ON SHORE)	8" AND ABOVE	PE 3408 DR17 CLASS C (BLACK) ASTM D3035 ASTM F714	BUTT FUSION FLANGE DR17 Class C (BLACK) ASTM D3261 150# ANSI B16.5	FULL FACE NEOPRENE 1/8" THICK	316 STAINLESS	BUTT FUSION DR17 Class C (BLACK) ASTM D3261 150# ANSI B16.5	BUTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS	–
BALLAST WATER (ON SHIP)	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28		–	–

SHT	INDEX
1	COVER – MATERIALS, PUMPS, EQUIPMENT, SYMBOLS, INDEX
2	ONE-LINE PIPING DIAGRAM. LCL, OPTION #1
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7	SECTION – ITLCL, OPTION #1
8	CARGO HOSE DOCK ARRANGEMENT. OPTION #1
9	LOADING ARM DOCK ARRANGEMENT. OPTION #2

LCL = LARGE CAPACITY 1000' LAKER
ITLCL = INTERMEDIATE TO LARGE CAPACITY 1000' LAKER

MAJOR EQUIPMENT LIST

QTY.	ITEM	MAKE	MODEL	CAPACITY	DRIVE/NOTES
4	LOADING ARM	EMCO WHEATON	16 IN. LOADING ARM	18,200 GPM	(OPTION 2)
5	WATER TRANSFER HOSE	TITAN INDUSTRIES	HEAVY DUTY WATER 21 IN. SIZE	16,200 GPM	(OPTION 1)
10	WATER STORAGE TANK	–	ø91 FT x 58 FT	2,818,911 GAL	MUNICIPAL SEWAGE OPTION
5	HOSE HANDLING CRANE	HYDRA-PRO CRANE	HP40-7T W/ WIRELESS REMOTE	15,680 LBS 40 FT REACH	OPTION 1
1	BACKUP GENERATOR BOOSTER PUMPS	–	–	1,414 kW	MUNICIPAL SEWAGE OPTION
1	BACKUP GENERATOR SEWAGE FEED PUMP	–	–	32 kW	MUNICIPAL SEWAGE OPTION
#	–	–	–	–	–
#	–	–	–	–	–
#	–	–	–	–	–
#	–	–	–	–	–
#	–	–	–	–	–

PUMP LIST

QTY.	SERVICE	TYPE	MODEL	CAPACITY	DRIVE
5	BALLAST WATER TRANSFER (MUNICIPAL SEWER)	CENTRIFUGAL	TACO GT45043	13,000 GPM 115 FT H20	500 HP MOTOR 460V/3P/60HZ NOTE 1
2	SEWAGE FEED PUMP (MUNICIPAL SEWER)	CENTRIFUGAL	GOULDS 24GHC	6,500 GPM 20 FT H20	40 HP MOTOR 460V/3P/60HZ NOTE 1

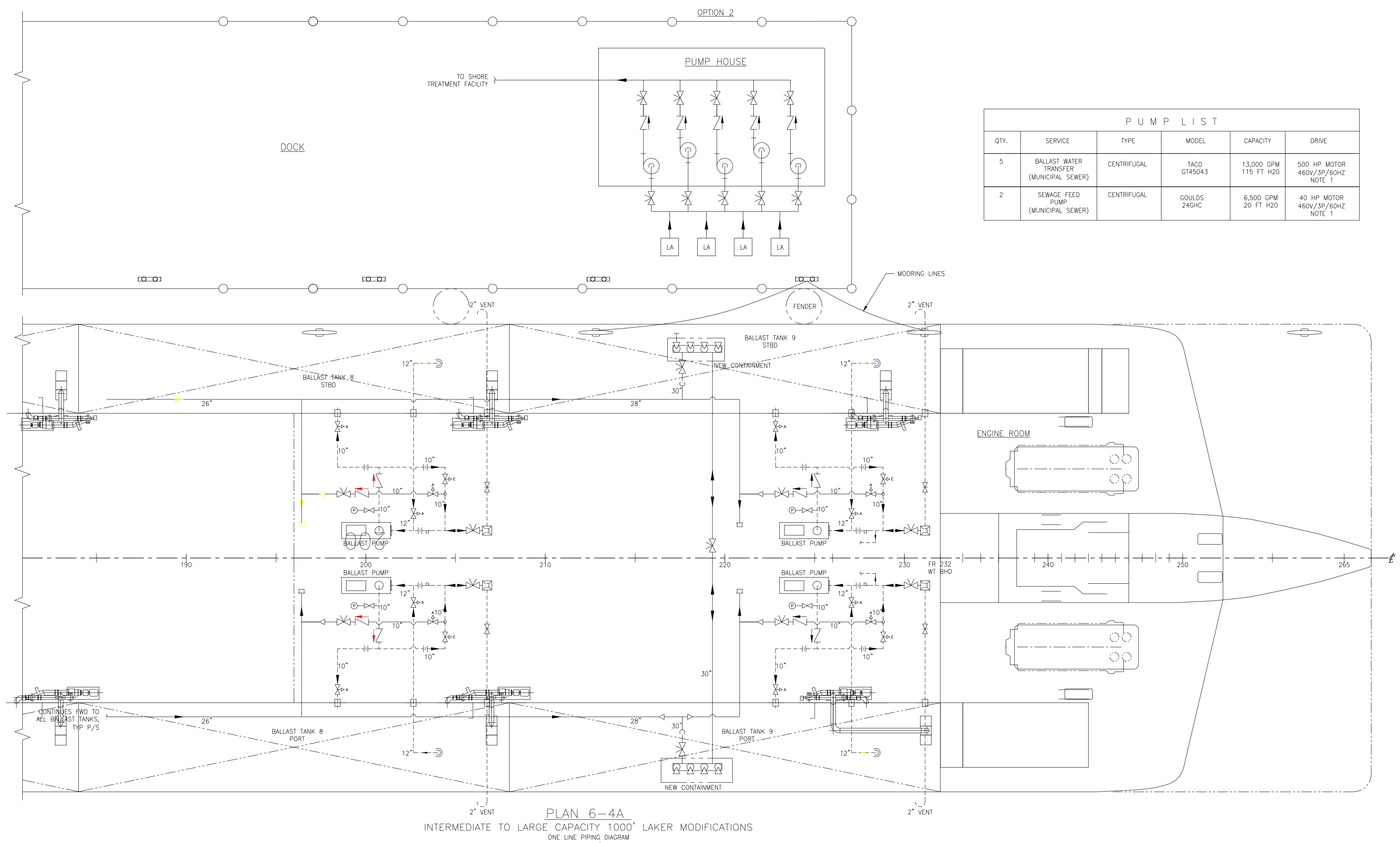

Figure G-1. Vessel One, Alternate BWM methods: piping diagram.

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2. Connect the 30" pipe to a manifold on the main deck. Install a suitable collar to provide structural compensation for the hull penetration.
3. Above the deck, install a 30" stop-check valve. There is a similar and opposite installation for the starboard side.

There is a manifold on each side the vessel. The manifolds will be connected with a 30" pipe that is routed transversely across the vessel.

G.1.3 Vessel One, Alternate BWM Methods: Manifold Location

The following information describes the location of the new ballast water manifold on the port side. The starboard manifold will be similar and opposite to the port manifold.

For the longitudinal location, the aftermost point of the manifold will be located approximately 20' forward of the deckhouse forward bulkhead. Position the manifold to not interfere with any existing ship structure or machinery. The manifold should be positioned so the manifold and its associate shore-side equipment are clear of existing equipment. Shore-side equipment may include hoses, hose cranes, and loading arms.

For the transverse location, the inboard-most point of the manifold will be located outboard of the line of deck hatches by at least 1'. The outboard-most point of the manifold will be located inboard of the deck edge at the main deck by at least 15'.

The manifold will be located vertically so that the centerline of the attachment flanges is located 4.0' above deck. The reference point for the deck will be the main deck at the side edge.

G.1.4 Vessel One, Alternate BWM Methods: Manifold Details

The following details describe the construction details of the port side manifold; see Figure G-2. A similar design will be used for each vessel.

The body of the manifold will be square tube, with internal dimensions of 42" wide x 42" high x 128" long. Orient the manifold so that the long dimension of the body runs fore-aft with the ship. Provide end caps to the body of the manifold. All plate thicknesses will be suitable for anticipated fluid pressures.

The shore connection pipe will attach to the aft end of the manifold body. Position the shore connection pipe in the center of the aft end plate of the manifold body. Install a 30" butterfly valve in the shore connection pipe just before the pipe attaches to the manifold body.

The manifold body will include four takeoffs to attach shore connection hoses. The center point of each takeoff will be centered between the top and bottom faces of the manifold body. Distribute the four takeoffs so that they are evenly spaced along the length of the outboard side face of the manifold body. Include the following details for each of the four individual takeoffs. Each individual takeoff shall be 16" nominal diameter. Install a 16" pipe directly onto the outboard side face of the manifold body. As close to the manifold as possible, install a 16" butterfly valve with flanged connections. Install a 150# 16" diameter bolted flange 6" after the butterfly valve. Bolt a quick-disconnect apparatus onto the 16" flange. Exact types of quick disconnect apparatus will be decided later. Provide a cap for each quick disconnect fitting.

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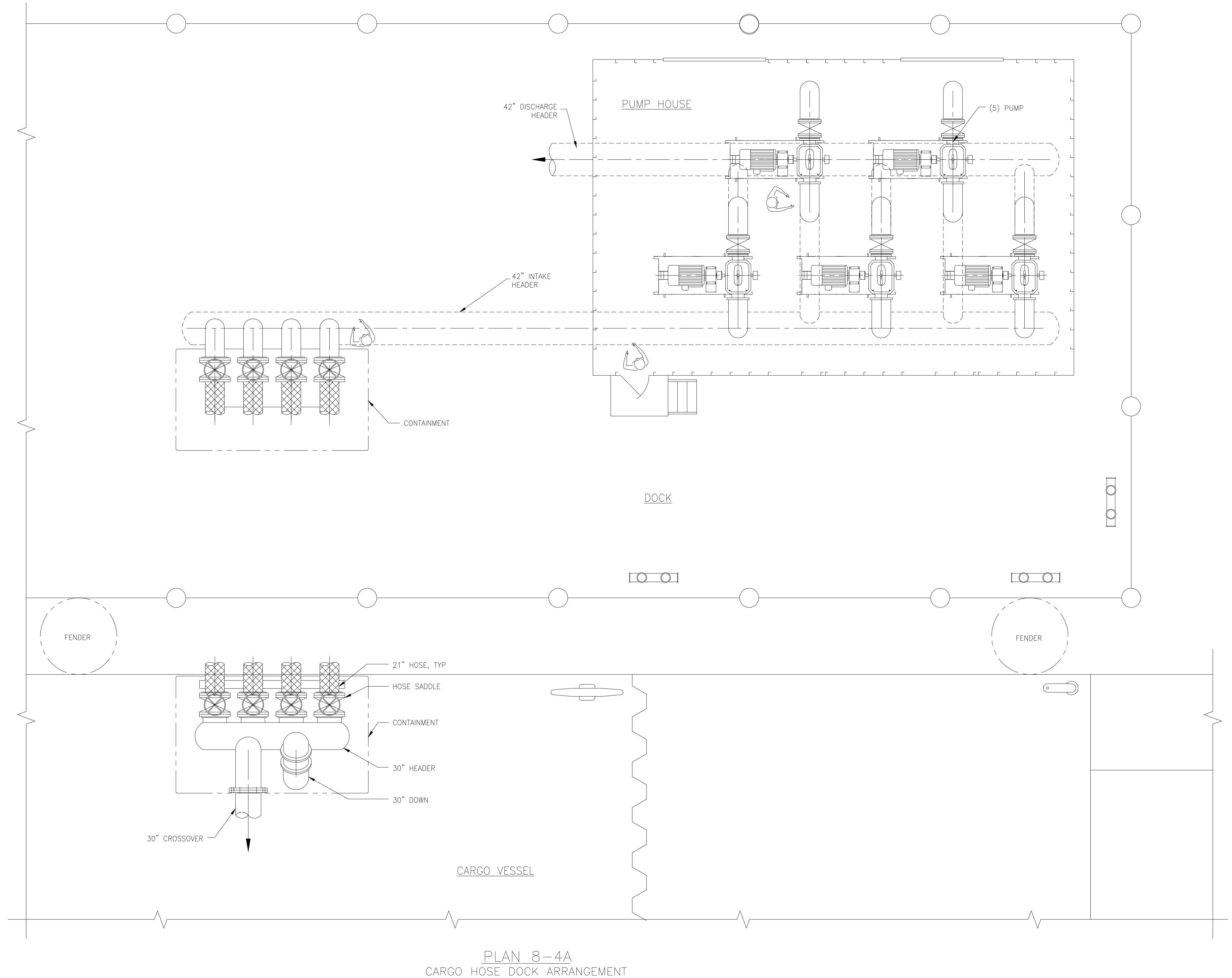

Figure G-2. Vessel One, Alternate BWM methods: manifold design.

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Install two drainage pipes on the bottom of the manifold body. The first drainage pipe will be located 6” forward of the aft face of the manifold body. The second drainage pipe will be located 6” aft of the forward face of the manifold body. Each drainage pipe will be 1” pipe diameter and extend 4” down below the manifold body. Attach the drainage pipe to the manifold body with a 1” diameter socket weld half coupling. Install a 1” diameter butterfly valve in the drainage pipe, as close to the manifold body as possible. Ensure that the manifold body does not interfere with rotation of the butterfly valve handle. Provide external threading at the end of the drainage pipe and install a screwed cap on the end.

Include a spill catch basin around the manifold. Basin shall extend in dimensions to enclose the manifold and all pipe takeoffs. Basin height shall be 24” Install a ½” threaded half coupling in the wall of the basin, as close to the deck as possible. Install a ½” full coupling in the deck, inside the catch basin. The deck side of the coupling will be threaded type. The other side of the coupling will be socket type. Mount coupling flush with the deck. Install ½” diameter pipe to drain the catch basin into the nearest ballast tank. Include a ½” plug threaded into the coupling installed in the main deck.

G.1.5 Vessel One, Alternate BWM Methods: Installation Costs

The estimated cost to install the shore connection is $1,121,321; see Table G-1.

Table G-1. Vessel One, Alternate BWM methods: cost estimate of vessel modifications.

SWBS No.	Item Description	Labor Hours	Material & Services @ Cost ($)	Subcontracts @ Cost ($)	Labor Cost @ $70/Hr	Material & Services w/17% Mark-up ($)	Subcontracts w/17% Mark-up ($)	Item Total Costs	Percent of Total Cost
000	Project Management & Admin	157	$244,140	$--	$10,976	$285,644	$--	$296,620	26.45%
100	Structure	2284	$21,675	$--	$159,893	$25,359	$--	$185,252	16.52%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	0	$--	$--	$--	$--	$--	$--	0.00%
400	Electronics & IC Systems	242	$605	$--	$16,934	$708	$--	$17,642	1.57%
500	Auxiliary Systems	2129	$47,137	$--	$149,018	$55,151	$--	$204,169	0.00%
600	Outfitting	1400	$44,576	$--	$98,000	$52,154	$--	$150,154	13.39%
700	Shore Side Loading Arms & Piping	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	134	$111,776	$--	$9,408	$130,778	$--	$140,186	12.50%
900	Shipyard Support Services	1579	$42,627	$--	$110,544	$49,874	$--	$160,418	14.31%
	Contingency @ 18%							**$171,049**	**15.25%**
	Based on Concept Design Level								
	Totals for All Items	**21584**	**$916,085**	**$--**	**$1,510,875**	**$1,071,819**	**$--**	**$1,121,321**	**100%**

G.2 Vessel Two, Alternate BWM Methods: Alternate Piping Modifications

G.2.1 Vessel Two, Alternate BWM Methods: Ballast System

The design changes are for an existing ballast system divided into two systems, each operating independently. The systems service the port and starboard ballast tanks independently. If any cross-connection exists between ballast systems, it is closed and not utilized. This section describes the existing port ballast system; starboard side is assumed similar and opposite.

The port ballast system also includes a single stripping pump, with a pumping capacity of 3,000 gpm (681.4 m^3/hr) through a 12" diameter pipe. The pump feeds into a 14" diameter pipe that leads to an overboard discharge at the 16' 9" (5.11 m) waterline. The overboard discharge is fitted with a 14" globe valve with a remote operator at the main deck.

G.2.2 Vessel Two, Alternate BWM Methods: Shore Connection Pipe

The shore connection pipe requires two pipes to connect into each ballast system; see Figure G-3. All modifications are listed for the port ballast system. The starboard ballast system modifications are similar and opposite. The design installs a vertical riser to bypass the overboard discharge. The changes to the system are:

1. The first location is just inboard of the main ballast sea chest, before the sea valve. The new pipe is nominal pipe size (NPS) 30" connected by a saddle with full penetration welding.
2. Just after the connection, the new pipe has a 30" diameter butterfly valve.
3. The second location that the new pipe attaches is at the discharge of the stripping pumps.
4. The new pipe attaches to the existing stripping system just inboard of the sea valve. The attachment is a 14" saddle T-connection, with full penetration welds.
5. This 14" pipe has a 14" butterfly valve fitted into the new pipe just after the connection with the existing pipe (USCG E1-02, 2002). The 14" pipe attaches to the 30" pipe via a saddle, Y-connection.

The shore connection pipe travels vertically upward through the main deck to the manifold:

1. Deck penetrations must be watertight with a reinforced collar.
2. Just after the deck penetration, a 30" stop-check valve should be installed.
3. The ballast piping on the main deck must be transversely located outboard from the line of the cargo hatches. Piping is 30" diameter.
4. Piping runs forward on top of the main deck until it reaches the manifold. Suitable foundations and coating should be provided for all piping.

A cross-connection pipe should be installed between the port side shore connection pipe and the starboard side shore connection pipe:

1. This cross-connection runs transverse across the top of the main deck.
2. The cross-connection pipe is 30" diameter.
3. The connections at the manifold are T-type saddle with full penetration welds.

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MATERIAL SCHEDULE									
SERVICE	SIZE	PIPE	TAKEDOWN JOINTS			FITTINGS	VALVES		REMARKS
			MATERIAL	GASKETS	BOLTING		BODY	TRIM	
BALLAST WATER (ON SHORE)	ALL	PVC SCH 80 ASTM D1785	SOCKET FLANGE PVC 150# ASTM D2467 ANSI B16.5	FULL FACE NEOPRENE 1/8" THICK	316 STAINLESS	PVC SCH 80 SOCKET UNION ASTM D2467 THREADED ASTM D2464 ASTM 1498	BUTTERFLY: PVC, ANSI B16.10 BALL: PVC, TRUE UNION ENDS	PVC DISC, SS STEM, FPM SEALS PVC BALL, SS STEM, FPM SEALS	-
BALLAST WATER (ON SHORE)	8" AND ABOVE	PE 3408 DR17 CLASS C (BLACK) ASTM D3035 ASTM F714	BUTT FUSION FLANGE DR17 Class C (BLACK) ASTM D3261 150# ANSI B16.5	FULL FACE NEOPRENE 1/8" THICK	316 STAINLESS	BUTT FUSION DR17 Class C (BLACK) ASTM D3261 150# ANSI B16.5	BUTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS	-
BALLAST WATER (ON SHIP)	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28		-	-

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3	ONE-LINE PIPING DIAGRAM. LCL, OPTION #2
4	SECTION – LCL, OPTION #1
5	ONE-LINE PIPING DIAGRAM. ITLCL, OPTION #1
6	ONE-LINE PIPING DIAGRAM. ITLCL, OPTION #2
7	SECTION – ITLCL, OPTION #1
8	CARGO HOSE DOCK ARRANGEMENT. OPTION #1
9	LOADING ARM DOCK ARRANGEMENT. OPTION #2

LCL = LARGE CAPACITY 1000' LAKER
ITLCL = INTERMEDIATE TO LARGE CAPACITY 1000' LAKER

MAJOR EQUIPMENT LIST					
QTY.	ITEM	MAKE	MODEL	CAPACITY	DRIVE/NOTES
4	LOADING ARM	EMCO WHEATON	16 IN. LOADING ARM	18,200 GPM	(OPTION 2)
5	WATER TRANSFER HOSE	TITAN INDUSTRIES	HEAVY DUTY WATER 21 IN. SIZE	16,200 GPM	(OPTION 1)
10	WATER STORAGE TANK	–	ø91 FT x 58 FT	2,818,911 GAL	MUNICIPAL SEWAGE OPTION
5	HOSE HANDLING CRANE	HYDRA-PRO CRANE	HP40-7T W/ WIRELESS REMOTE	15,680 LBS 40 FT REACH	OPTION 1
1	BACKUP GENERATOR BOOSTER PUMPS	–	–	1,414 kW	MUNICIPAL SEWAGE OPTION
1	BACKUP GENERATOR SEWAGE FEED PUMP	–	–	32 kW	MUNICIPAL SEWAGE OPTION
#	–	–	–	–	–
#	–	–	–	–	–
#	–	–	–	–	–
#	–	–	–	–	–
#	–	–	–	–	–

SYMBOLS LIST	
	NEW PIPE
	EXISTING PIPE
	BUTTERFLY VALVE REMOTE CONTROLLED
	BUTTERFLY VALVE
	BALL VALVE
	PIPE DOWN
	SWING CHECK VALVE
	FLANGE CONNECTION (QUICK CONNECT)
	CENTRIFUGAL PUMP
	BUTTERFLY VALVE MANIFOLD
	REDUCER
LA	MARINE LOADING ARM
	BHD/DECK PENETRATION
	SUCTION BELLMOUTH
	VENT
	BUTTERFLY VALVE REMOTELY OPERATED (AIR) W/ CAPABILITY OF MANUAL OPERATION
	DRESSER COUPLING W/ ANCHOR BOLTS
P	PRESSURE GAUGE
	BUTTERFLY VALVE REMOTELY OPERATED (ELEC) W/ CAPABILITY OF MANUAL OPERATION
	PLUG
	1/2" COUPLING & PLUG
	FLEXIBLE CONNECTION

PUMP LIST					
QTY.	SERVICE	TYPE	MODEL	CAPACITY	DRIVE
5	BALLAST WATER TRANSFER (MUNICIPAL SEWER)	CENTRIFUGAL	TACO GT45043	13,000 GPM 115 FT H20	500 HP MOTOR 460V/3P/60HZ NOTE 1
2	SEWAGE FEED PUMP (MUNICIPAL SEWER)	CENTRIFUGAL	GOULDS 24GHC	6,500 GPM 20 FT H20	40 HP MOTOR 460V/3P/60HZ NOTE 1

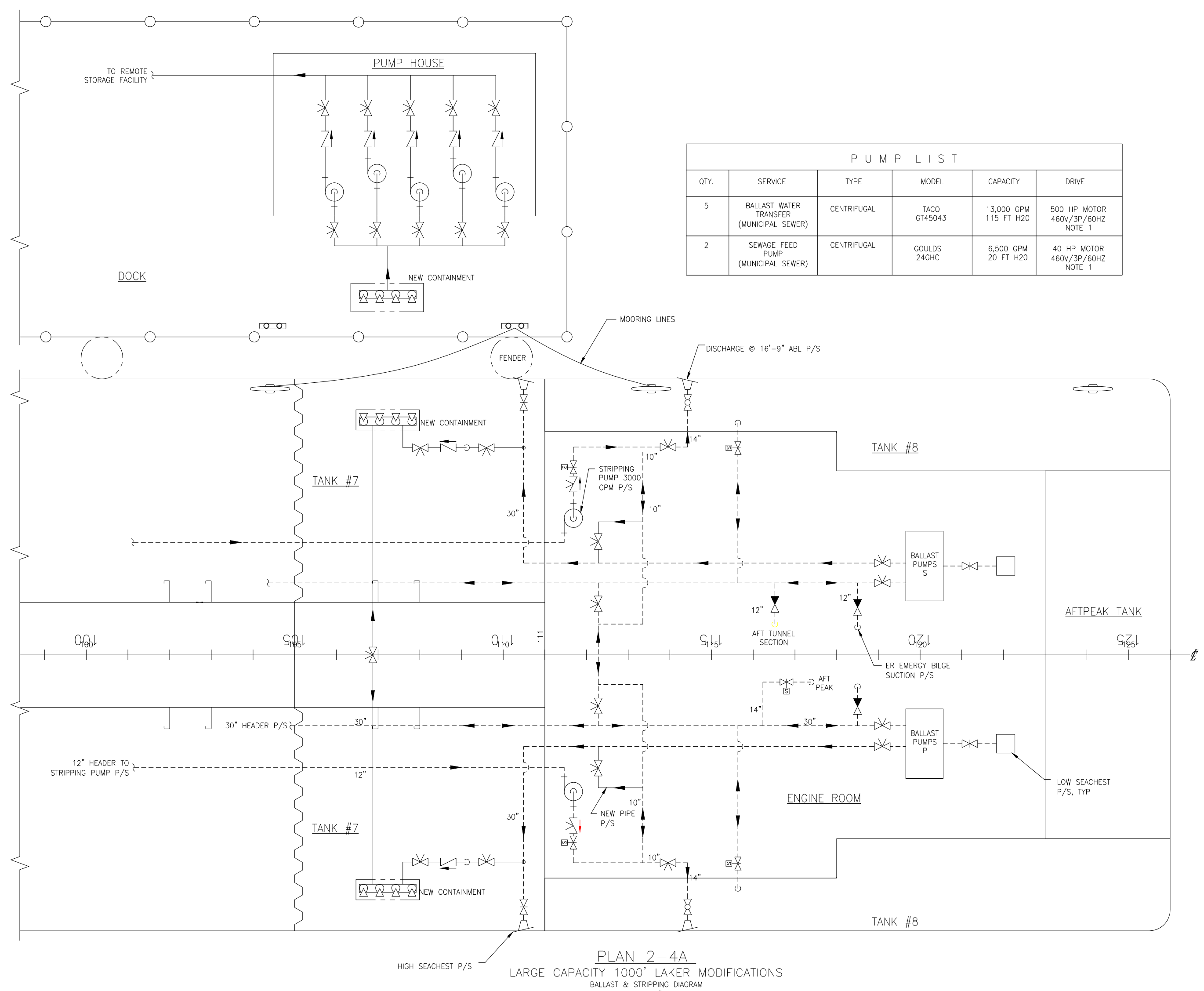

Figure G-3. Vessel Two, Alternate BWM methods: piping diagram.

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G.2.3 Vessel Two, Alternate BWM Methods: Manifold Details

The manifold location and design will be similar to Vessel One; see Figure G-2.

G.2.4 Vessel Two, Alternate BWM Methods: Installation Costs

The estimated cost to install the shore connection is $758,482; see Table G-2.

Table G-2. Vessel Two, Alternate BWM methods: cost estimate of vessel modifications.

SWBS No.	Item Description	Labor Hours	Material & Services @ Cost ($)	Subcontracts @ Cost ($)	Labor Cost @$70/Hr	Material & Services w/17% Mark-up ($)	Subcontracts w/8% Mark-up ($)	Item Total Costs	Percent of Total Cost
000	Project Management & Admin	55	$114,886	$--	$3,842	$134,417	$--	$138,259	18.23%
100	Structure	804	$6,973	$--	$56,285	$8,159	$--	$64,444	8.50%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	0	$--	$--	$--	$--	$--	$--	0.00%
400	Electronics & IC Systems	0	$--	$--	$--	$--	$--	$--	0.00%
500	Auxiliary Systems	2129	$47,137	$--	$149,018	$55,151	$--	$ 204,169	26.92%
600	Outfitting	591	$41,731	$--	$41,372	$48,826	$--	$90,197	11.89%
700	Shore-side Installation	3145	$129,437	$--	$220,150	$151,441	$--	$--	0.00%
800	Integration & Engineering	0	$58,800	$--	$--	$68,796	$--	$68,796	9.07%
900	Shipyard Support Services	672	$25,536	$--	$47,040	$29,877	$--	$76,917	10.14%
	Contingency @ 18% Based On Concept Design Level							**$115,701**	**15.25%**
	Totals For All Items	**7396**	**$424,501**	**$--**	**$517,707**	**$496,666**	**$--**	**$758,482**	**100%**

G.3 Vessel Three, Alternate BWM Methods: Alternate Piping Modifications

G.3.1 Vessel Three, Alternate BWM Methods: Ballast System

The ballast system is comprised of one electric motor-driven pump on each side for a total of two. The combined capacity is 21,000 gpm or 4,770 mt per hour with a total dynamic head (TDH) of 40'. The ballast system is a manifold and single line per tank type, with the single lines leading down each side of the vessel in the ballast tanks in a raft of pipes. The line for each ballast tanks (1-8) is a 10" diameter pipe, with a 6" diameter branch line for the forepeak tank. Each ballast tank suction line is fitted with a suction box located close to the vessel bottom.

G.3.2 Vessel Three, Alternate BWM Methods: Modifications

The ballast system pumps for Vessel Three are located in the engine room, similarly to Vessel Two. The modification for a shore connection will be similar to Vessel Two. A riser will be added, which bypasses the overboard discharge; see Figure G-4. The riser connects to a manifold on the main deck, similar construction as shown in Figure G-2. There is a manifold cross-connect on the main deck.

MATERIAL SCHEDULE									
SERVICE	SIZE	PIPE	TAKEDOWN JOINTS			FITTINGS	VALVES		REMARKS
			MATERIAL	GASKETS	BOLTING		BODY	TRIM	
BALLAST WATER (ON SHORE)	ALL	PVC SCH 80 ASTM D1785	SOCKET FLANGE PVC 150# ASTM D2467 ANSI B16.5	FULL FACE NEOPRENE 1/8" THICK	316 STAINLESS	PVC SCH 80 SOCKET UNION ASTM D2467 THREADED ASTM D2464 ASTM 1498	BUTTERFLY: PVC, ANSI B16.10 BALL: PVC, TRUE UNION ENDS	PVC DISC, SS STEM, FPM SEALS PVC BALL, SS STEM, FPM SEALS	–
BALLAST WATER (ON SHORE)	8" AND ABOVE	PE 3408 DR17 CLASS C (BLACK) ASTM D3035 ASTM F714	BUTT FUSION FLANGE DR17 Class C (BLACK) ASTM D3261 150# ANSI B16.5	FULL FACE NEOPRENE 1/8" THICK	316 STAINLESS	BUTT FUSION DR17 Class C (BLACK) ASTM D3261 150# ANSI B16.5	BUTTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS	–
BALLAST WATER (ON SHIP)	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28		–	–

SYMBOLS LIST
NEW PIPE
EXISTING PIPE
BUTTERFLY VALVE REMOTE CONTROLLED
BUTTERFLY VALVE
BALL VALVE
PIPE DOWN
SWING CHECK VALVE
CENTRIFUGAL PUMP
BUTTERFLY VALVE MANIFOLD
BHD/DECK PENETRATION
SEACHEST
VENT
BALLAST WATER TRANSFER HOSE
SUCTION BELLMOUTH
GATE VALVE
OVERBOARD DISCHARGE

MAJOR EQUIPMENT LIST					
QTY.	ITEM	MAKE	MODEL	CAPACITY	DRIVE/NOTES
5	WATER TRANSFER HOSE	TITAN INDUSTRIES	HEAVY DUTY WATER 16 IN. SIZE	–	(OPTION 1)
5	HOSE HANDLING CRANE	HYDRA-PRO CRANE	HP40-7T W/ WIRELESS REMOTE	15,680 LBS 40 FT REACH	OPTION 1

PUMP LIST					
QTY.	SERVICE	TYPE	MODEL	CAPACITY	DRIVE
5	BALLAST WATER TRANSFER (DEDICATED BWT)	CENTRIFUGAL	GOULDS 3420 SIZE 20"x24"	13,000 GPM 38 FT H20	50 HP MOTOR 460V/3P/60HZ NOTE 1

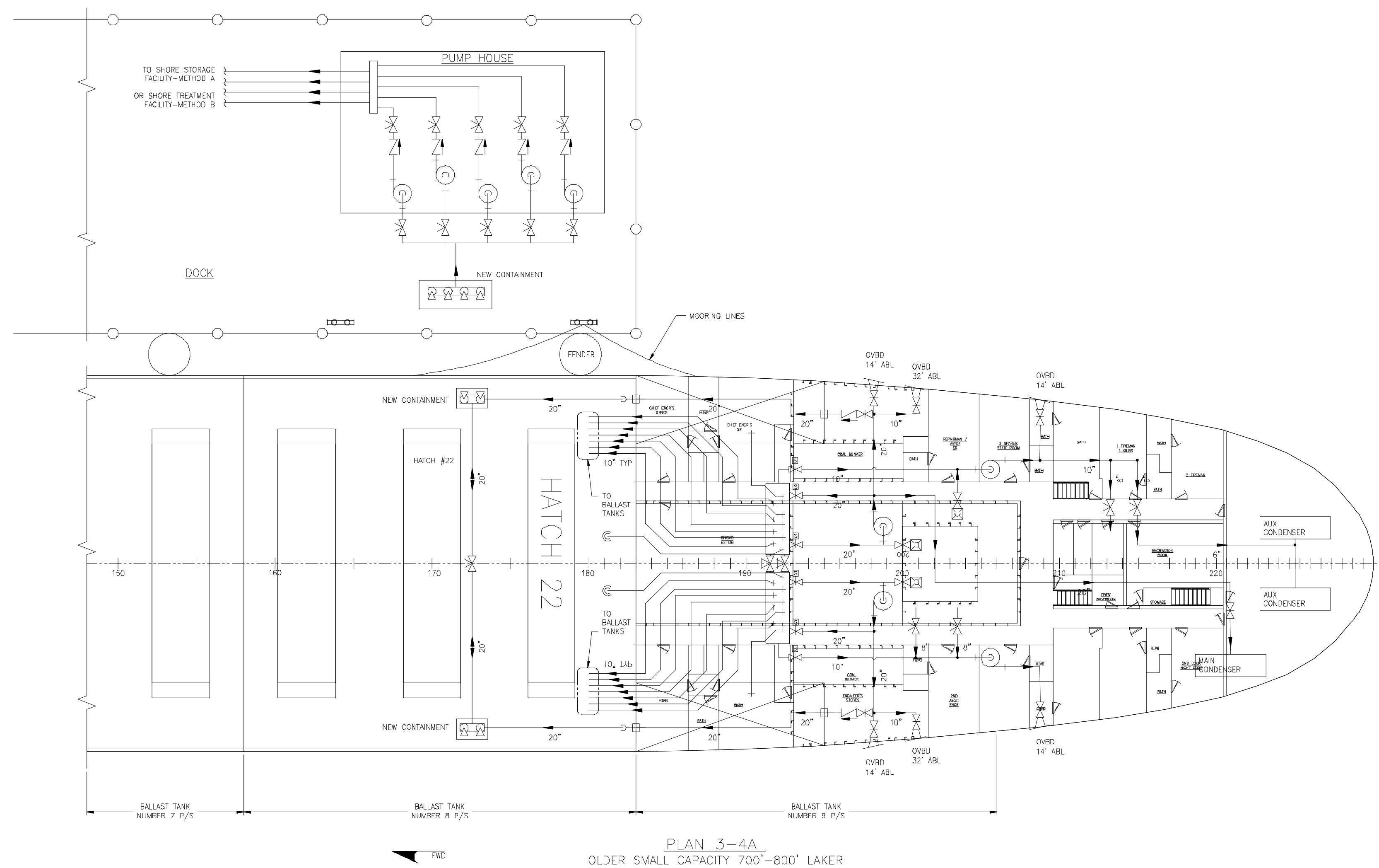

Figure G-4. Vessel Three, Alternate BWM methods: piping diagram.

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G.3.3 Vessel Three, Alternate BWM Methods: Installation Costs

The estimated cost to install the shore connection is $594,866; see Table G-3.

Table G-3. Vessel Three, Alternate BWM methods: cost estimate of vessel modifications.

SWBS No.	Item Description	Labor Hours	Material & Services @ Cost ($)	Subcontracts @ Cost ($)	Labor Cost @$70/Hr	Material & Services w/17% Mark-up ($)	Subcontracts w/17% Mark-up ($)	Item Total Costs	Percent of Total Cost
000	Project Management & Admin	38	$98,792	0	$2,681	$115,587	$0	$118,268	17.26%
100	Structure	693	$5,800	0	$48,500	$6,786	$0	$55,286	8.07%
200	Propulsion Machinery	0	$0	0	$0	$0	$0	$0	0.00%
300	Electrical System	0	$0	0	$0	$0	$0	$0	0.00%
400	Electronics & IC Systems	0	$0	0	$0	$0	$0	$0	0.00%
500	Auxiliary Systems	1877	$35,323	0	$131,387	$41,328	$0	$172,714	25.21%
600	Outfitting	591	$41,731	0	$41,372	$48,826	$0	$90,197	13.17%
700	Shore-side Piping	0	$0	0	$0	$0	$0	$0	0.00%
800	Integration & Engineering	0	$64,725	0	$0	$75,728	$0	$75,728	11.05%
900	Shipyard Support Services	681	$17,741	0	$47,667	$20,757	$0	$68,424	9.99%
	Contingency @ 18%							**$104,511**	**15.25%**
	Totals For All Items	**3880**	**$264,112**	**0**	**$271,606**	**$309,011**	**$0**	**$685,128**	**100.00%**

G.4 Vessel Four, Alternative BWM Methods: Alternate Piping Modifications

G.4.1 Vessel Four, Alternate BWM Methods: General System Description

The ballast system is comprised of one hydraulic motor-driven 14,000 gpm or 3,180 mt per hour pump on each side of the vessel with a combined capacity of 28,000 gpm or 6,360 mt per hour. The ballast piping system on this 740’ vessel is a single header leading down each side of the vessel and located in the ballast tanks with branch lines to each tank. The main header is a 24” diameter pipe for most of the length that tapers to a 12” diameter at the forward extreme, and the forepeak tank.

G.4.2 Vessel Four, Alternative BWM Methods: Modifications

The ballast system pumps for Vessel Four are located in the engine room, similarly to Vessel Two. The modification for a shore connection will be similar to Vessel Two. A riser will be added, which bypasses the overboard discharge; see Figure G-5. The riser connects to a manifold on the main deck, similar construction as shown in Figure G-2. There is a manifold cross-connect on the main deck.

SYMBOLS LIST
PIPE W/ FLOW DIRECTION
EXISTING PIPE W/ FLOW DIRECTION
BUTTERFLY VALVE REMOTELY OPERATED (ELEC THROTTLING) W/ CAPABILITY OF MANUAL OPERATION
BUTTERFLY VALVE REMOTELY OPERATED (AIR OPEN OR CLOSE) W/ CAPABILITY OF MANUAL OPERATION
BUTTERFLY VALVE
GLOBE VALVE
GATE VALVE
BHD/DECK PENETRATION
SWING CHECK VALVE
PRESSURE GAUGE
DRESSER COUPLING W/ ANCHOR BOLTS
CROSSING PIPES CONNECTED
CROSSING PIPES NOT CONNECTED
SUCTION BELLMOUTH
REMOTE ACTUATED BALL VALVE
CENTRIFUGAL PUMP
PRIMING VALVE
DECK PENETRATION

MATERIAL SCHEDULE

SERVICE	SIZE	PIPE	TAKEDOWN JOINTS			FITTINGS	VALVES	
			MATERIAL	GASKETS	BOLTING		BODY	TRIM
BALLAST WATER	ALL	CARBON STEEL ASTM A53 SCH STD ANSI B36.10	FLANGE CARBON STEEL 150# SLIP-ON ASTM A105 ANSI B16.5	GARLOCK STYLE 3300 OR EQUAL	316 STAINLESS	CARBON STEEL BUTT WELD, BLACK SCH STD ASTM A234 GRADE WPB ANSI B16.9 OR ANSI B16.28	BUTTERFLY DUCTILE IRON BODY WAFER OR FLANGED ASTM A395 ANSI B16.34	STAINLESS STEEL RENEWABLE DISC & SEAT, EPDM SEALS & SEATS

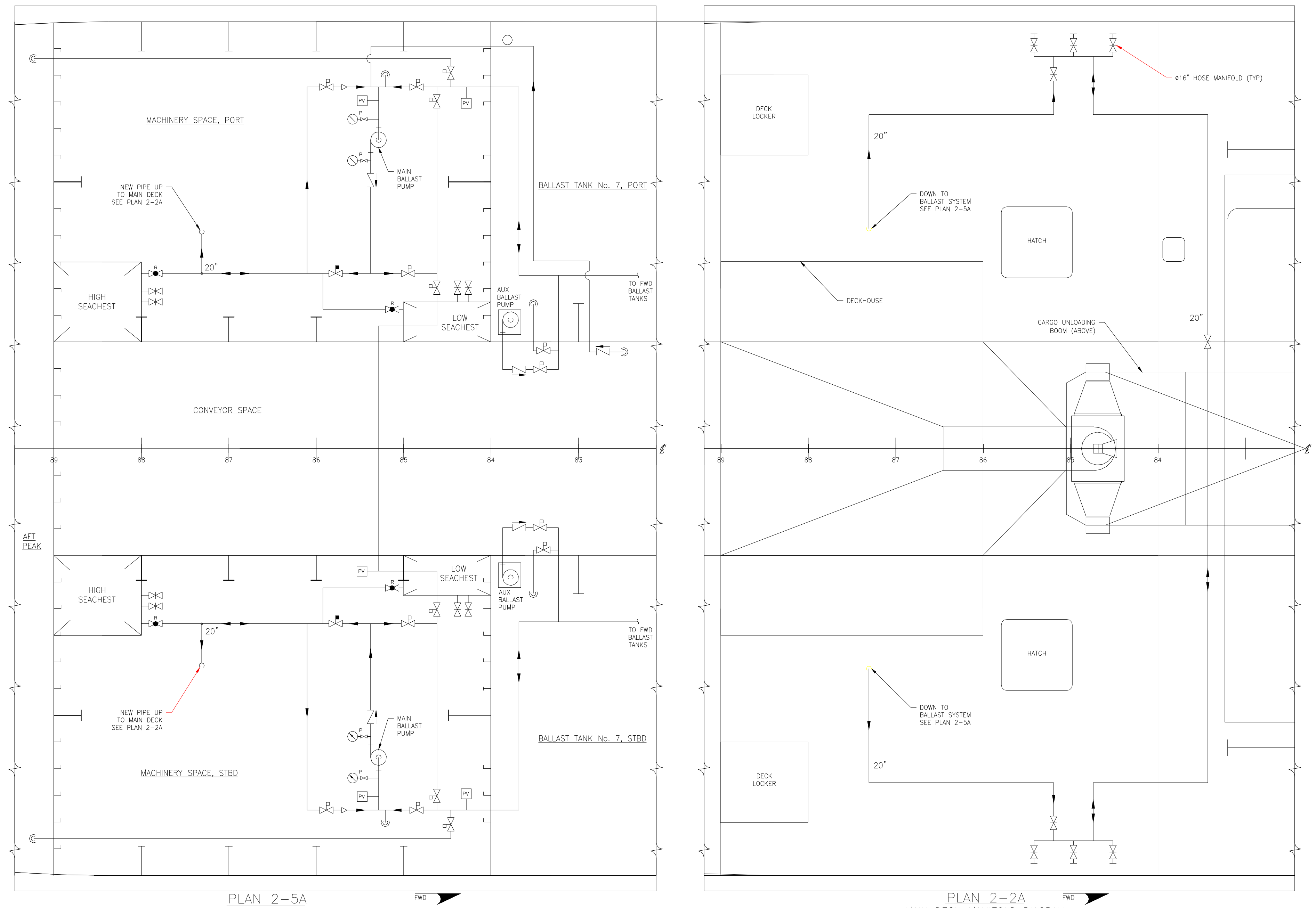

Figure G-5. Vessel Four, Alternate BWM methods: piping diagram.

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G.4.3 Vessel Four, Alternative BWM Methods: Installation Costs

The estimated cost to install the shore connection is $594,866; see Table G-4.

Table G-4. Vessel Four, Alternate BWM methods: cost estimate of vessel modifications.

PRELIMINARY COST ESTIMATE SUMMARY: SHORE-SIDE DISCHARGE OPTION NO. 1 (CRANES & HOSES)									
SWBS No.	**Item Description**	**Labor Hours**	**Material & Services @ Cost ($)**	**Subcontracts @ Cost ($)**	**Labor Cost @$70/Hr**	**Material & Services w/17% Mark-up ($)**	**Subcontracts w/17% Mark-up ($)**	**Item Total Costs**	**Percent of Total Cost**
000	Project Management & Admin	34	$103,261	$--	$2,399	$120,815	$--	$123,214	20.71%
100	Structure	669	$4,456	$--	$46,836	$5,214	$--	$52,049	8.75%
200	Propulsion Machinery	0	$--	$--	$--	$--	$--	$--	0.00%
300	Electrical System	0	$--	$--	$--	$--	$--	$--	0.00%
400	Electronics & IC Systems	0	$--	$--	$--	$--	$--	$--	0.00%
500	Auxiliary Systems	1485	$37,517	$--	$103,921	$43,895	$--	$147,815	24.85%
600	Outfitting	538	$19,040	$--	$37,632	$22,277	$--	$59,909	10.07%
700	Shore-side Piping	0	$--	$--	$--	$--	$--	$--	0.00%
800	Integration & Engineering	67	$50,288	$--	$4,704	$58,837	$--	$63,541	10.68%
900	Shipyard Support Services	577	$14,717	$--	$40,376	$17,219	$--	$57,595	9.68%
	Contingency @ 18% **Based on Concept Design Level**							$90,742	15.25%
	Totals for all Items	**3370**	**$229,279**	**$--**	**$235,867**	**$268,256**	**$--**	**$594,866**	**100%**

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